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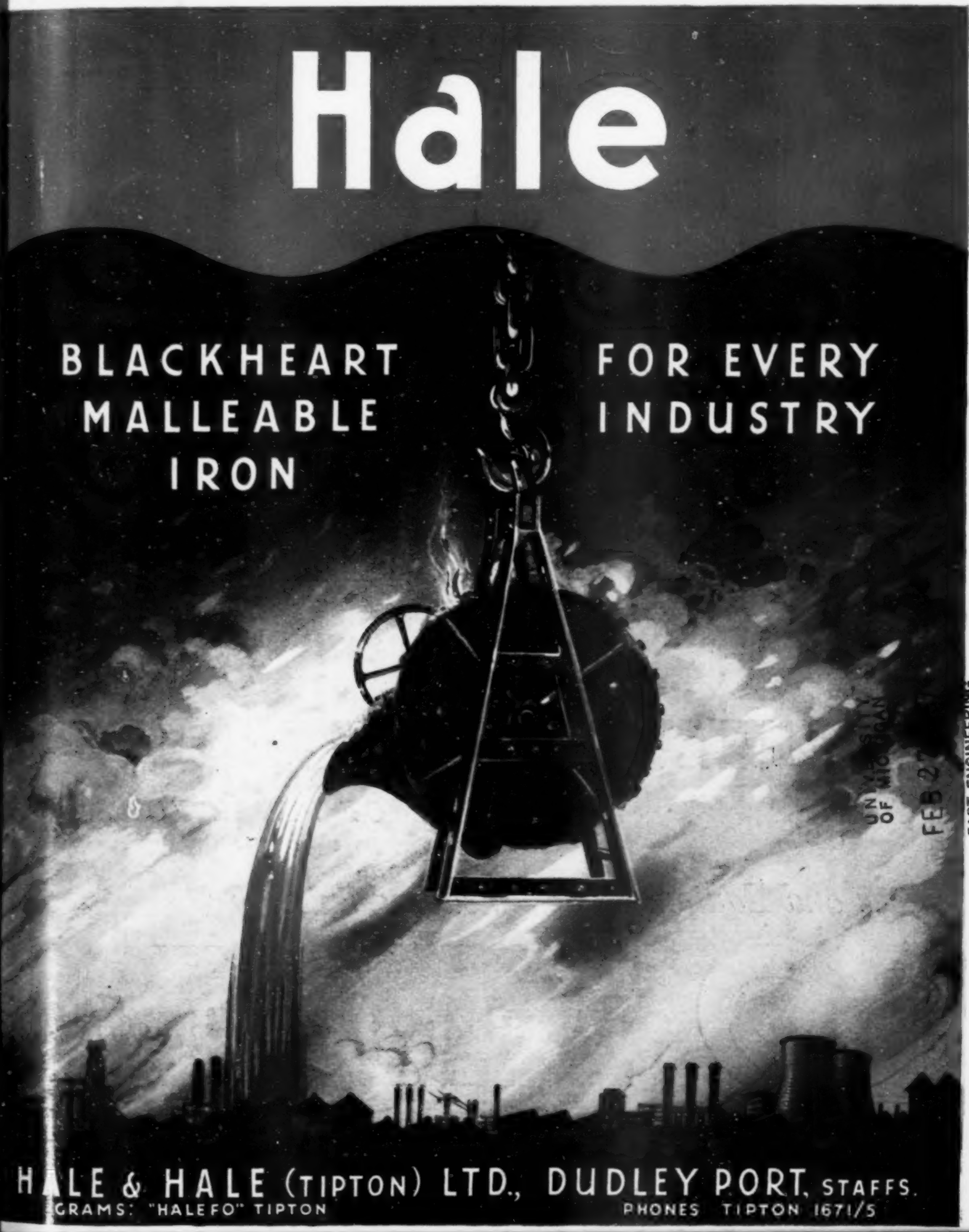

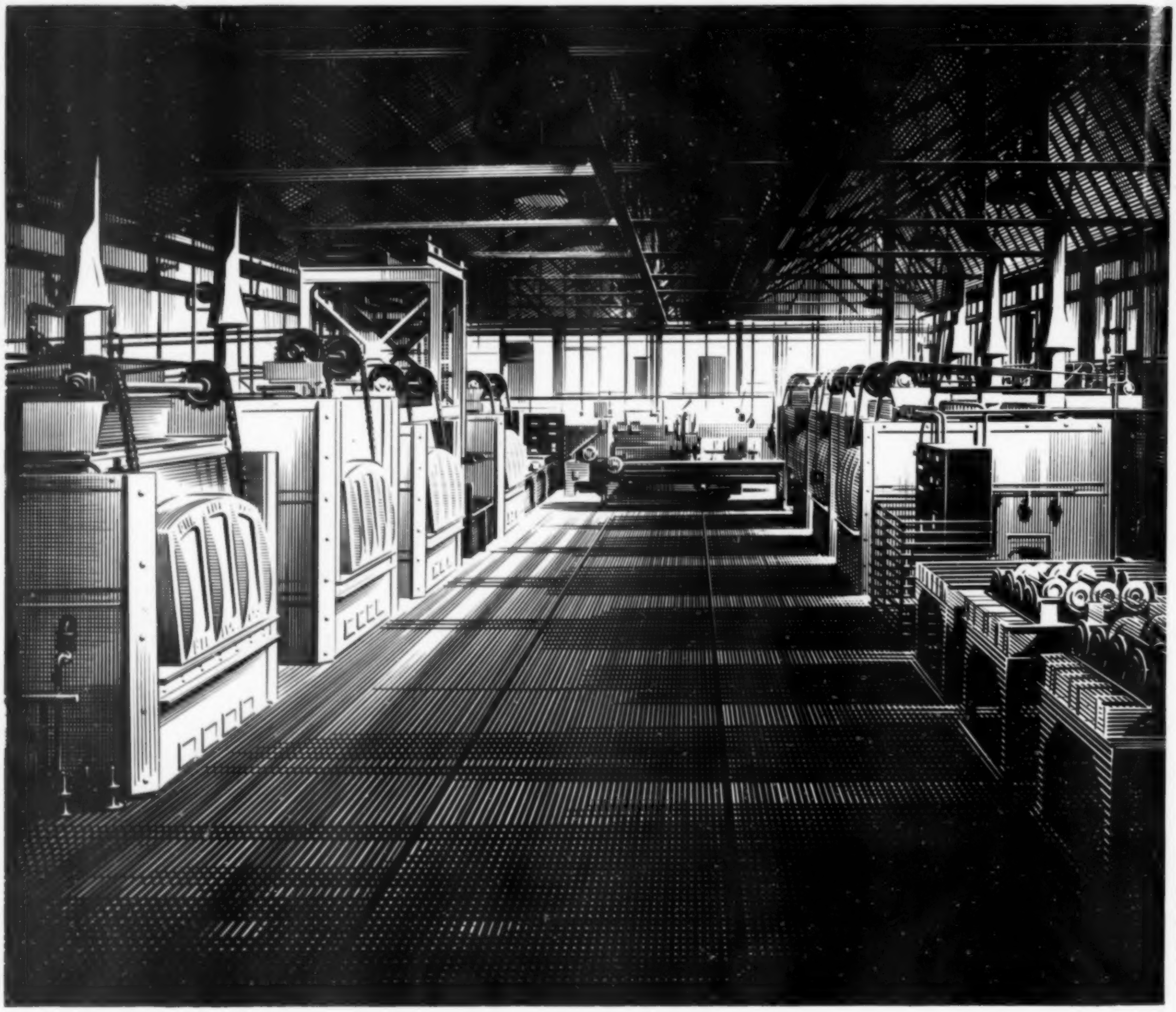

METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE "METALLURGICAL ENGINEER"

FEBRUARY, 1957 Vol. LV. No. 328

Steel Expansion

TWELVE months ago, the steel industry looked forward confidently to an output of 21¼ million tons in 1956, an outlook based on the 1955 production of 19·8 million tons and the increased capacity due to become available. On this occasion, however, the target was missed by about half a million tons, a loss in output almost entirely attributed to the maintenance craftsmen's ban on overtime, which lasted from April to August. No sooner was that dispute settled than the restriction of oil supplies due to the closing of the Suez Canal cast a shadow over the otherwise bright prospect for the coming year. Nearly 8 million tons of steel are produced in oil-fired furnaces each year, and many soaking pits, reheating furnaces and finishing facilities depend on oil, even where the steel is produced with the aid of other fuels. Although it will be possible to make good the deficit, at least in part, by the use of creosote-pitch, output is bound to be affected by the restriction of the total supply of liquid fuel, and by the adjustments necessary to achieve the desired substitutions. Furthermore, the cuts in diesel oil supplies will have their effect on the transport of the 100 million tons of material involved in the production of the 22¾ million tons of steel planned for 1957.

This output target was based on the full use throughout the year of the facilities brought into operation during 1956, and the new capacity expected to become available in 1957. Five new blast furnaces and eight new open-hearth furnaces are due to come into production during the year, in addition to Bessemer and electric steelmaking developments. No fewer than 358 coke ovens are due to be completed, of which 192 are for replacement. Among major rolling mill developments will be a new 4-stand billet mill and two new heavy section mills at Dorman Long, a new medium-width hot-strip mill at Steel, Peech & Tozer, a new bar and rod mill at Samuel Fox, a plate mill extension at South Durham, and a new cogging mill at Firth-Vickers.

In the view of the British Iron and Steel Federation, as expressed in the latest issue of *Steel Review*, even if oil supplies were assured, it is most unlikely that the home market could absorb an extra 1½ million tons of steel in 1957, particularly in view of the high level of consumer stocks, as it would require an increase of 8% in consumption to do so. This, in view of the decrease in the production of metal goods resulting from the measures taken to deal with inflation, scarcely seems possible. Much of the increase in steel production would, therefore, have been expected to reduce imports, although in view of the shortage of plates and heavy sections, substantial tonnages of these products may continue to be imported.

Looking further ahead, the Federation estimates possible output in 1958 at 23½ million tons, 7 million tons more than in 1952, when the second post-war development plan began. As compared with 1955, the 1958 output of light rolled products is expected to rise by 1·1 million tons, of heavy sections and bars by 700,000 tons, and of plates by 300,000 tons.

For some time, the industry has been thinking in terms of a possible demand of 28 million tons of steel by 1962, which, if met from home production, would require pig iron production approaching 20 million tons. Developments which will affect production after 1958 have already been worked out in detail, and many have been submitted for central approval. These already go a long way towards the programme envisaged for 1962; they include seven new blast furnaces, five new melting shops, five new plate mills, and major developments in heavy sections, re-rolled products, billets, tinplate, and sheet, as well as special steels.

Because a heavy demand for steel has been maintained in recent years, and because the industry has consistently increased its output year by year, there is a tendency to believe that it is only necessary to raise the target for production to rise too. That this is far from being the case was stressed by Sir Ellis Hunter, Chairman and Managing Director of Dorman, Long & Co., Ltd., in his recent statement to the shareholders. Expansion of the industry is dependent on the availability of adequate labour, raw materials, fuel and finance.

The industry's capital expenditure has been directed towards increasing output by higher productivity, with little increase in the labour force employed, but it is unlikely that the increase in production envisaged can be achieved without extra labour. On the raw material side, too, competition for the available foreign ores will be keen, and it will be necessary to have the requisite shipping available to bring them to this country. Again, any increase in production of home ores will involve underground mining, with its attendant labour problems. Although water could hardly be described as a raw material of the industry, enormous quantities are used, and its availablility is therefore, very important. Nor must it be forgotten that increased production will mean a corresponding increase in inland transport, particularly by rail. Judging by the production figures issued by the National Coal Board, merely increasing output by the extra millions of tons needed by the steel industry would be no easy matter, but the fact that most of it must be of a good coking quality presents even greater problems. The difficulties associated with raw materials, labour shipping, etc., have been foreseen, of course, and steps have been taken to minimise their influence.

On the question of finance, the Federation estimates that the industry will need to spend about £100 million a year on fixed assets during the period 1958–62, and with an additional investment in stocks and work-in-progress at around £15 million a year, the total for the five years is likely to reach £575 million, or more if prices continue to rise. This is what will be needed if the industry is to meet the nation's requirements for steel. Whether such a target can be reached depends on whether steel prices are such as to enable the industry to acquire the funds needed, either from the market or from retained profits.

Meeting Diary

5th February

Institute of Metals, Oxford Local Section. Junior Members' Evening. Discussion on "Surfaces." Cadena Cafe. Cornmarket Street, Oxford. 7 p.m.

Sheffield Metallurgical Association. "Spectography," by M. Z. de Lippa. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

6th February

Institute of Welding, Manchester and District Branch. "Welding in the Coal Industry," by S. C. Walker. Reynolds Hall, College of Technology, Manchester. 7-15 p.m.

7th February

Institute of Metals, London Local Section. "Beryllium," by Bengt Kjellgren. 17, Belgrave Square, London, S.W.1. 6-30 p.m.

Leeds Metallurgical Society. "Fuel Ash Corrosion Problems," by Professor A. Preece. Large Chemistry Lecture Theatre, The University, Leeds, 2. 7-15 p.m.

8th February

North East Coast Institution of Engineers and Shipbuilders. "Ceramic Materials for High-Temperature Gas Turbines," by Dr. T. H. Blakeley and R. F. Darling. Mining Institute, Newcastle-on-Tyne. 6-15 p.m.

11th February

Institution of Production Engineers, Sheffield Section. "Continuous Casting," by I. M. D. Halliday. The Grand Hotel, Sheffield. 6-30 p.m.

12th February

Institute of Marine Engineers. "Boiler Feed Water Treatment for Advanced Steaming Conditions," by J. Leicester, and two papers on "Corrosion in Scotch Marine Boilers," by Dr. F. Wormwell, Dr. G. Butler, J. G. Beynon and H. C. K. Ison. Institute of Marine Engineers, 85, Minories, London, E.C.3. 5-30 p.m.

Institute of Metals, South Wales Local Section. "Neutron Irradiation Effects in Metals," by Professor J. G. Ball. Department of Metallurgy, University College, Singleton Park, Swansea. 6-45 p.m.

Institution of Production Engineers, Birmingham Graduate Section. "The Properties and Some Uses of Titanium," by R. L. Preece. The James Watt Memorial Institute, Great Charles Street, Birmingham. 7 p.m.

Sheffield Metallurgical Association. "Radioactive Isotopes in Industrial Research" by Dr. D. H. Houseman. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

13th February

Institution of Production Engineers, London Graduate Section. "The Design and Production of Die Castings in Zinc Base and Aluminium Alloys," by P. A. R. Findlay. The Institution of Production Engineers, 10, Chesterfield Street, London, W.1. 7-15 p.m.

Manchester Metallurgical Society. "Titanium," by Dr. J. W. Rodgers. Manchester Room of The Central Library, Manchester. 6-30 p.m.

14th February

Institute of British Foundrymen, Beds./Herts. Section. "Behaviour of Moulding Sands at High Temperatures," by W. B. Parkes. Small Assembly Room, Town Hall, Luton. 7-30 p.m.

Institute of Metals, Birmingham Local Section. "Modern Developments in Forging, Rolling and Extrusion," by Prof. A. R. E. Singer. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham. 6-30 p.m.

Liverpool Metallurgical Society. "Work Hardening and Dislocation Theory," by Dr. A. H. Cottrell. Liverpool Engineering Society, The Temple, Dale Street, Liverpool. 7 p.m.

15th February

Institution of Mechanical Engineers. Thomas Hawksley Lecture. "Some Engineering Problems in the Industrial Development of Nuclear Energy," by Sir Claude Gibb, C.B.E., F.R.S. (By ticket only.) Church House, Westminster, London, S.W.1. 6 p.m.

West of Scotland Iron and Steel Institute. "The Heat, Fuel and Power Balances in an Integrated Steel Works," by J. A. C. Cowan and J. Roberts. 39, Elmbank Crescent, Glasgow. 6-45 p.m.

18th February

Institute of Metals, Sheffield Local Section. "Radiation Damage to Metals," by Dr. W. M. Lomer. Engineering Lecture Theatre, The University, St. George's Square, Sheffield, 1. 7-30 p.m.

Institution of Production Engineers, Coventry Section. "Case Hardening Processes," by L. G. W. Palethorpe. The Craven Arms, High Street, Coventry. 7 p.m.

19th February

Institute of British Foundrymen, East Anglian Section. "Refractories for Foundries and Furnaces," by Dr. W. Ford. Lecture Hall, Public Library, Ipswich. 7-30 p.m.

Institute of British Foundrymen, Slough Section. "Mechanical Properties of Test-bars and Castings," by Dr. E. Scheuer. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7-30 p.m.

North East Metallurgical Society. "Metallurgical Principles of Light Alloy Foundry Practice," by Dr. W. A. Baker. Cleveland Scientific and Technical Institution, Middlesbrough. 7-15 p.m.

Sheffield Metallurgical Association. "Brittle Fracture in Ductile Material," by Dr. S. A. Main. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

20th February

Institution of Production Engineers, Birmingham Section. "The Measurement and Use of Welding Costs," by A. G. Thompson. The James Watt Memorial Institute, Great Charles Street, Birmingham. 7 p.m.

Institution of Production Engineers, Derby Section. "Powder Metallurgy," by Dr. P. R. Marshall. The Irongates Hotel, Irongate, Derby. 7 p.m.

Institution of Production Engineers, Wolverhampton Graduate Section. "The Field of Application of Automatic Arc Welding," by J. A. Lucey. The Wolverhampton and Staffs. Technical College, Wulfruna Street, Wolverhampton. 7-30 p.m.

Society of Chemical Industry, Corrosion Group. "Theory and Practice in Potential Measurements for Cathodic Protection," by P. W. Heselgrave. Society of Chemical Industry, 14, Belgrave Square, London, S.W.1. 6-30 p.m.

22nd February

Institution of Mechanical Engineers. "Principles and Applications of Spark Machining," by D. W. Rudorff. 1, Birdcage Walk, Westminster, London, S.W.1. 6 p.m.

Society of Instrument Technology, Scottish Section. "Strain Gauge Instruments and their Application," by G. H. Laycock. Building Centre, 425, Sauchiehall Street, Glasgow. 7-15 p.m.

25th February

Incorporated Plant Engineers, West and East Yorkshire Branch. "Fuel and the Future," by Dr. A. L. Roberts. The University, Leeds. 7-30 p.m.

26th February

Sheffield Metallurgical Association. "Some Metallurgical Aspects of Creep Resisting Steels," by D. J. Murray. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

27th February

Institute of British Foundrymen, London Branch. "Methods Engineering with Emphasis on the Flow Process applied to Fettling-shop Control," by F. Gaiger and R. Hancox. Constitutional Club, Northumberland Avenue (south-east from Trafalgar Square), London, W.C.2. 7-30 p.m.

Institute of Fuel. "Measurements of Size Droplets from Convergent-Divergent Nozzles used in Oil Burners for Steel Furnaces," by E. J. Burton and J. R. Royce. Institution of Civil Engineers, Great George Street, London, S.W.1. 5-30 p.m.

Manchester Metallurgical Society. "Mechanism of Diffusion," by A. D. LeClaire. Manchester Room of The Central Library, Manchester. 6-30 p.m.

28th February

Institute of Metals, Birmingham Local Section. "Nickel Alloys with Special Properties in the Field of Physics and Electrical Engineering," by C. Gordon Smith. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham. 6-30 p.m.

The Aluminium Supply Position

By E. G. West, Ph.D., B.Sc., F.I.M.
Technical Director, Aluminium Development Association

Since the author last reviewed the aluminium supply position in this journal, much progress has been made in further increasing world output, and the present article summarises recently published information on ingot capacity. It indicates that, in addition to projected increases in the capacities of existing smelters, there is a trend towards the establishment of smelters near the raw material deposits—a trend on which the development of nuclear power may have considerable bearing.

SINCE the last review of the aluminium supply position appeared in METALLURGIA[1], much progress has been made in further increasing world output, and the present article summarises information recently published on ingot capacity.

During the first half of this century it had become almost axiomatic that aluminium production should double every decade, and this geometric progression is apparently continuing in the period 1950–60. Peak aluminium production during the war was almost 2 million metric tons,* and many doubted whether any increase could be absorbed for many years. In the event, the 1943 peak was greatly surpassed within less than ten years, and the schemes now in hand will provide a world capacity of 5 to 5·5 million tons by 1960.

The international nature of the aluminium industry has been noted on many occasions, and the present survey shows how closely integrated must be the operations of mining, refining the ore, and smelting, followed by fabrication and usage. It indicates also the almost unique place which Britain holds in the aluminium industry of the world, with its fabricating capacity turning out more than ten times its primary metal production. Supplies of virgin aluminium must therefore be assured at a price which will permit competition in world markets both for "semis" and for consumer goods embodying the maximum proportion of aluminium.

This review is divided into four parts dealing, respectively, with the following aspects of supply and demand:

(1) Notes on Aluminium Production Technology.
(2) Future Aluminium Requirements.
(3) Current and Projected Virgin Metal Production.
(4) Development of Usage.

Aluminium Production Technology

The smelting of aluminium involves two basic steps, namely, the production of pure alumina (aluminium oxide) from the ore, and the electrolytic reduction of this alumina in a cell in which it is dissolved in fused cryolite (sodium aluminium fluoride), with additions of other compounds. The electrolytic process requires from 7·5 to 9 kilowatt hours of electricity for each pound of metal produced, so that production plants have normally been sited where hydro-electric power is available. Taking a round figure of 20,000 kWh. per ton of metal smelted, it will be seen that present production at 3·5 million tons requires 7×10^{10} kWh. or $9{\cdot}4 \times 10^{10}$ h.p. hr. The cost of aluminium thus includes a factor for electric power used for reduction which varies between 12% and more than 15% of the total.

* Annual rates unless otherwise stated.

Alumina is usually produced from the ore, bauxite, by the Bayer process, which may be operated near the source of hydro-electric power or at the mine. In either case, a major part of the cost of aluminium production is transportation, for each ton of aluminium produced may require the movement of 8–10 tons of material. Each ton of metal is reduced from 2 tons of alumina, which in turn is obtained form 4–6 tons of bauxite by treatment with caustic soda. Chemicals must be transported to the alumina works, and other materials—petroleum coke, cryolite, fluorspar, etc.—are required at the smelter. There is an increasing tendency to treat the ore near to the mines, in order to reduce the bulk to be conveyed to the smelting areas, which are generally located in remote parts of the world where cheap power is available. This situation may, of course, change when nuclear energy stations are able to supply electricity at a sufficiently low cost, as the power supply may then be located virtually on the ore bed. The type of load taken by an aluminium smelter should be ideal for supply by nuclear reactors, as it is required continuously over long periods.

Ore Treatment

Bauxite has hitherto been used exclusively for aluminium production—in particular, ores containing a minimum of 50% aluminium oxide. Of even greater importance than the aluminium content, however, is the proportion of silicon and iron oxide. Thus, up to 7% silicon can be treated satisfactorily by the Bayer process, in which the ore is digested with caustic soda to dissolve out the aluminium. From this solution it is precipitated as aluminium hydroxide, which is subsequently calcined to alumina. Modifications to the original process have made it possible to deal with ores containing up to 15% silicon, and other ores, such as Jamaican bauxite, require yet a further modification to permit removal of the higher iron contents, and to take account of the difference in the form of the aluminium oxide itself.

All clays are aluminium-bearing, and other minerals from which aluminium may be extracted include nepheline, syenite, anorthosite, leucite and alunite. A number of processes have been developed for treating ores other than bauxite, but hitherto, under normal conditions, none has proved economic. The most promising process involves heating the ore with limestone in a kiln, which yields a lime-sinter product from which alumina can be extracted by the same general reactions as in the Bayer process. Much larger quan-

TABLE I.—PRODUCTION OF PRIMARY ALUMINIUM AND TOTAL CONSUMPTION OF ALUMINIUM AND ITS ALLOYS.*
(thousands of metric tons)

Country	1929†		1938‡		1950		1955	
	Production	Consumption	Production	Consumption	Production	Consumption	Production	Consumption
U.K.	14	31	23	63	30	167	28	350
Canada	29	7	65	5·5	360	65	590	80
Australia	nil	0·7	nil	0·3	nil	10	1	12
U.S.A.	103	126	130	133	651	911	1500	1800
France	29	27	45	31	60	45	139	75
Germany	33	37	161	173	30(W)	20(W)	145(W)	200(W)
Italy	7	9	26	26	37	39	65	68(E)
Switzerland	20	8	27	9	21	14	30	
Norway	29	1	29	1	46	4	80	
Austria	3		4	4	18	9	45	
Russia	?		44		210		430(E)	
Jugoslavia	nil		1		2	2·5	10	5
Hungary			1		7		40(E)	
India	nil		nil		3·5	5·5	10	12
Japan	nil	12	17	27	25	14	60	90
China			1		20			

Notes.—* Based on Paley Report plus later published data. † Peak year of 1920's. ‡ Last pre-war year. W, West Germany only. E, Estimated.

tities of raw material must be handled, however, and there is also the extra cost of sintering. Fuel requirements are higher than those for the Bayer process, and estimates vary from 50% to several hundreds per cent above those for treating bauxite. These differences are very significant when it is remembered that 1 ton of aluminium can be extracted from 4 tons of bauxite. When using clay, however, at least twice as much material has to be treated initially, namely, 8–10 tons per ton of aluminium. With bauxite, approximately 1 ton of soda and other chemicals is required to yield 1 ton of alumina, but when treating clay, up to 12 tons of soda, limestone and other materials must be handled. This higher cost may be offset by the sale of by-products, such as cement, and this possibility was taken into account when an American Government sponsored project was undertaken during the war at Laramie, Wyoming. Here it was estimated some 10 tons of cement could be produced for each ton of alumina, but the cost of transporting the cement to the nearest markets may make such by-products uneconomic. Another alternative would be to use oil-bearing shales, from which the oil could be extracted before the alumina. When account is taken of the other principal factor in aluminium production, namely, transportation, some deposits of suitable clays or other non-bauxite minerals might be worked without long hauls of materials, and the higher cost of processing might be largely offset by the lower cost of transport.

Interest has recently been aroused again by the Anaconda Company, which is now a producer of virgin aluminium, and which is planning to spend a million dollars in developing commercially the extraction of alumina from clay. A pilot plant is to be set up with a capacity of 50 tons of aluminium oxide per day. World interests await the result of this full-scale experiment, particularly as it may have repercussions on the treatment of Bayer process residues, which may contain a high proportion of alumina. Efforts were made during World War II to extract this residual alumina by sintering, but in normal circumstances this additional operation is uneconomic.

TABLE II.—U.K. CONSUMPTION OF ALUMINIUM AND OTHER NON-FERROUS METALS (PRIMARY PLUS SCRAP).
(Thousands of long tons)

Year	Aluminium	Copper	Lead	Zinc
1920	15	100	158	120
1930	24	142	283	168
1940	135	440		
1945	150	462	294	250
1946	201	493	317	290
1947	267	541	317	316
1948	243	538	314	310
1949	247	497	328	288
1950	268	526	328	330
1951	316	554	341	284
1952	281	672	240	255
1953	230	526	237	270
1954	267	682	255	325
1955	350	780	280	345

Transportation

It is significant that aluminium smelters are already being located other than at hydro-electric power sites, and today there is a swing towards locating plants where transportation costs are lower, but where power derived from steam plants is rather more expensive. This is especially noticeable in the U.S.A., where new smelting units have recently been sited on the eastern areas of the industrial Ohio river. Here, ore or alumina can be transported by barge from the Southern State bauxite deposits and smelted with the aid of steam-produced power, the metal then being conveyed over short distances to the fabricating sections of the industry. Thus, the higher cost of power produced from steam or natural-gas plants is counter-balanced by the reduced costs of transporting material to and from the smelter. Germany has also used its coal deposits for power for the aluminium industry, and it is now possible to look forward to the use of nuclear power for aluminium smelting. This may mean a major break with the past, as the electric power might be produced at the ore bed, thus reducing transportation to a negligible proportion of the total costs of metal production. On certain sites it might even be possible to manufacture the chemicals used for refining the ore, again using power from the atomic pile.

The financial resources required to develop new productive capacity are immense; for example a figure of £1,000 per ton of smelter capacity is often taken as a basic capital cost for new projects. For each thousand tons of aluminium per annum an investment of £1 million is thus necessary, and few smelters are likely to be installed in future with a capacity of less than 10,000 tons per annum. Whilst this cost of £1,000 per ton of metal produced might be high for some projects, it would be considerably exceeded in many parts of the world today, and nuclear energy plants may well mean an increase in this figure for initial cost.

Future Aluminium Requirements

In June 1952 there was published in the U.S.A. the so-called Paley Report—" A Report on Resources for Freedom "—in Volume II[2] of which considerable attention was devoted to aluminium. This covered mainly American requirements, and it predicted for the U.S.A. " a demand in the neighbourhood of 4·5 million short tons by 1975, or nearly five times the level of consump-

tion of 1950." It was expected that old scrap would constitute an increasing proportion of the metal required, and that by 1975 it might reach 20% of total consumption, compared with 10% in the early 1950's. The Report thus contemplated an American demand for primary aluminium in 20 years' time of about 3·6 million short tons, or four times the U.S.A. consumption of primary metal in 1950. Most commentators at the time considered that these predictions were very optimistic, or even fantastic, but four years later it was beginning to appear that they were either very reasonable, or even pessimistic!

Recent estimates by two of the principal American producers indicate that the rate of growth of aluminium production for American use must be appreciably higher than the estimates of the Paley Committee, one considering that 4 million short tons of virgin aluminium will be required by 1965, and the other expecting that 5 million tons will be consumed by 1975.

The conclusions of the Paley Report are a valuable pointer to world aluminium consumption, as the trend in all industrial countries is on the same general lines. The statement in the Paley Report that "aluminium has not yet found its normal relative place in the materials demand of the American economy" is equally true in Britain and the European countries. The increased consumption envisaged is based partly on the replacement of other non-ferrous metals by aluminium, and to an even greater extent by the replacement of steel and timber by aluminium. The Report estimated the demand of the free world, excluding America, at some 2·4 million tons by 1975, or a five-fold increase since 1950. This is an average annual rate of increase in aluminium consumption of 5%, which is regarded as conservative by many aluminium producers and fabricators today. Thus, according to Appendix I of the recently issues Report[3] on the Volta river project, the U.K. demand for aluminium would seem to lie somewhere between 900,000 tons and 1·3 million tons in 1975, of which 720,000 tons and 1 million tons, respectively, would be met from virgin metal.

It can be assumed that the requirements of Russia and her satellites will be of at least the same order, with perhaps an even greater rate of increase than in the Western world, due to the present relatively low *per capita* consumption of aluminium in Communist countries.

The Position in Britain

In the 12 years that have elapsed since 1944/5, the curves of production and consumption have levelled out, and show that the war-time peaks have already been greatly surpassed. The broad picture of how the world aluminium situation affects Britain can be obtained from the figures in Tables I and II, which show, respectively, production and consumption of aluminium in the principal countries of the world, and consumption of aluminium and other non-ferrous metals in Britain.

The average annual production of virgin aluminium in the U.K. is some 30,000 tons a year, and total requirements are running at well over ten times this figure. With 75,000–95,000 tons being obtained by refining scrap, a substantial balance of virgin metal must be imported, and this is mainly obtained from Canada. The arrangements made between the U.K. Government and the Canadian producers, following British loans to finance war-time expansion, allow for the imports shown

TABLE III.—AMOUNT OF PRIMARY ALUMINIUM TO BE MADE AVAILABLE TO THE U.K. BY CANADA.

Year(s)	Annual Quantity (tons)
1956	263,000
1957	275,600
1958	303,100
1959/61	330,700
1962/70	303,100
1971/73	55,100

in Table III. It will be seen that these Canadian imports of aluminium will not yield all the metal that Britain is likely to require, and this undoubtedly influenced the decision in 1955 to undertake further smelting operations in Canada by a joint Canadian/British company. The possibilities of the Volta River project going forward must also be taken into account, as this would yield a further 200,000 tons of virgin metal a year in due course.

Bauxite

Bauxite is one of the most widely distributed minerals in the world, and the known reserves are in excess of 2,000 million tons. Some figures for these reserves are shown in Table IV, and there must be many other deposits of the ore which have not yet been accurately assessed.

From the original workings at Les Baux in Southern France, the mining of bauxite has spread to every Continent, and the Western World has relied largely on the mines of France, Greece and Jugoslavia, of West Africa and of the Guianas in South America. During the past four years, the great deposits of Jamaica have been opened up, and it was recently stated that the annual output from Jamaica had surpassed that of Surinam (Dutch Guiana). Up to the beginning of 1952, the U.S.A. relied largely on Surinam for its imports of bauxite, which then totalled nearly 2 million tons per annum. This was in addition to the lower grade deposits of native bauxite in Arkansas and other Southern States. In 1952, American smelters began receiving supplies from Jamaica, and by the end of 1955 the U.S.A. was importing approximately 2·5 million tons from both Jamaica and Surinam. The deposits in British Guiana were largely worked for export to the Canadian smelters at Arvida, and the Jamaican reserves were first developed by an Aluminium, Ltd., subsidiary in 1952. Bauxite in

TABLE IV.—BAUXITE RESERVES AND PRODUCTION.*

Principal Countries	Reserves†		Production (thousands of metric tons)		
	(millions of metric tons)	approx. % Al_2O_3	1938	1950	1955
France	60	61	682	804	1500
Jugoslavia	100	60	396	400	850
Greece	60	57	180	77	500(E)
Italy			370	153	320
British Guiana	65	61	382	1609	2300(E)
Dutch Guiana	50+	59	377	2060	3000(E)
Jamaica	315	50	nil	nil	2700(E)
Gold Coast	230	53	nil	116	120
French W. Africa	50	66	nil	10	500(E)
India	250	50–60+	15	57	85(E)
Indonesia	n.a.		240	490	250
Australia	200(E)		1	3	8
U.S.A.	50	50	297	1356	2000(E)
Brazil	150	61	13	20	20
Hungary	350	60	550	600	1300(E)
Russia	50		250	700	1950
China	600–800(E)		n.a.	n.a.	n.a.
World Total			4000	8900	17000(E)

* Based on Paley Report plus later published data.
† Reserves of ore are notoriously difficult to define owing to conservative initial estimates, revision of data as mining proceeds, and improvements in ore treatment which may make economic, ores previously regarded as useless.
(E) Estimated. n.a. not available.

Haiti and the Dominican Republic is now to be mined by American interests.

In West Africa, there is a flourishing bauxite mining industry which has been sending ore to British and other European smelters, and to North America, but within the past few years these deposits have become of increasing interest due to several plans for beneficiation of ore, making alumina and smelting aluminium in the same area. The Los Islands off French Guinea are new contributors of bauxite within recent years, some 250,000 tons having been exported annually between 1952 and 1954, increasing to double this quantity during last year. A new plant to use bauxite deposits in a hitherto undeveloped area of French Guinea has been recently announced jointly by Aluminium Ltd. and Bauxites du Midi. This development would involve the construction of new transport facilities from the mines to the Coast, with new storage and port areas and, eventually, construction of an alumina plant to treat the bauxite.

During the past year, new and important deposits of bauxite were discovered in Queensland, Australia, and a recent estimate has placed these at many hundreds of millions of tons. They are situated at Yeipa on the West Coast of Cape York Peninsula, and there has recently been formed a Queensland Company, the Commonwealth Aluminium Corporation, to exploit them.

News of additional deposits of bauxite in the U.S.S.R. and Far East are received fairly frequently, and it must be remembered that some of the largest bauxite mines now operating are in Hungary and Jugoslavia. Russia has also been reported as producing alumina from alunite and nepheline, although she has large reserves of bauxite, estimated in 1945 at some 50 million tons, of varying grades.

Alumina

Production of alumina from bauxite has grown in an impressive manner, and there has recently been published a useful review[4] showing the principal countries producing the oxide from the ore. In brief, it shows that 1955 output in Western Europe totals over one million tons, made up approximately as follows: *Germany*—approximately 500,000, divided among five producers; *France*—approximately 350,000, out of a maximum capacity of 450,000 tons; *Gt. Britain*—approximately 100,000 tons; *Italy*—165,000–190,000 tons; and *Norway*—an appreciably lower figure of possibly 20,000 tons.

In Eastern Europe the totals are approximately: *Jugoslavia*—50,000–65,000 tons; *Hungary*—154,000 tons; and *Russia*—in excess of 600,000 tons.

In *Canada*, alumina production in Quebec was just less than a million tons in 1943, but was raised to 1,200,000 tons in 1955.

In *Jamaica*, alumina is now being produced near the bauxite mines by an Aluminium, Ltd., subsidiary—Alumina Jamaica, Ltd.—to the extent of a quarter of a million tons a year, with considerable new capacity going into operation which may raise output to over a half million tons.

In the *U.S.A.*, alumina production in the hands of the aluminium smelters totals at least 3 million tons, and Reynolds Metals Company is already planning greater alumina production in Jamaica.

Other principal alumina producers are *Japan*—150,000–165,000 tons; *Brazil*—50,000 tons; and *India*—10,000 tons, rising to 40,000 tons in 1958.

One of the latest developments in the extraction of alumina from bauxite was announced recently by Aluminium, Ltd., namely, to locate a bauxite treatment plant at MacKenzie in British Guiana, where bauxite has been mined for the past 40 years. It is planned to produce 250,000 short tons of alumina from local bauxite within the next two to three years. This $30 million development has been made possible by developments in the ocean transport of bulk alumina. This will be particularly useful in Guiana, because the mouth of the Demarara River is blocked by a mud bar, which requires bauxite carriers to be topped up after the bar has been cleared.

Mention has already been made of the expansion of bauxite treatment in French West Africa and it appears that the new plant envisaged by Bauxites du Midi will produce 250,000 tons of alumina per annum within the next few years. This appears to be independent of the aluminium reduction plant in the Cameroons mentioned later in this article.

New Aluminium Production

In this section, the principal additions to aluminium productive capacity during the past few years are summarised, but while some of the projects are being actively pursued, in others construction has not yet commenced, and some are still at the stage of discussion and planning. As a result of the projects now in hand, it is possible that, during the next four years, world production will rise to at least 4·5 million tons, and some estimates place the increased output at more than 5 million tons.

BRITAIN: The possibilities of Britain increasing aluminium production at home are negligible, and even if there were major and unforeseen developments in the power situation, transport and handling of ore would militate against economic operation of large scale smelters here.

The British Aluminium Company has, however, become the major partner in a new concern, the Canadian British Aluminium Company, which has been formed in conjunction with the Quebec North Shore Paper Company to establish a new aluminium smelter at Baie Comeau. The site is on the North Shore of the St. Lawrence River in the Province of Quebec, and power facilities owned by the paper company are available to the new smelter. The eventual output will be 160,000 tons per annum, planned initially in four stages, the first of which will come into operation during 1958 with a capacity of 40,000 tons, and in 1959 of 80,000 tons. The cost of the scheme will be of the order of $120 million and good progress was made in 1956 with the construction of a new port, the smelter and houses. Recently, orders were placed with the British Thomson-Houston Company for plant to the value of £1,750,000, and with the English Electric Company for £500,000 worth of equipment for the initial stages. The British Aluminium Company is also interested in the Volta River Scheme, and in a recently announced expansion of Australian capacity.

VOLTA RIVER SCHEME: It will be recalled that a White Paper was published in November 1952 setting out the general scheme for using the hydro-electric potentialities of the Volta River on the Gold Coast for the production of aluminium. This has since been investigated in great detail by a Preparatory Commis-

sion, and a very interesting Report,[3] published recently, details all the technical and economic problems which will have to be solved to carry through this scheme, which is now under further discussion between the Governments of the two countries, The British Aluminium Co., Ltd., and Aluminium, Ltd.

In brief, the construction of a dam over 300 ft. high would create a lake covering approximately 3,500 square miles. The hydro-electric power available would amount to over 600,000 kW. and this would permit an ultimate annual production of over 200,000 tons of aluminium. At the initial stage, there would be capacity for approximately 80,000 tons of aluminium per annum, with an intermediate stage of 120,000 tons before the final total of 210,000 tons was achieved. The bauxite would be mined in the area and transported to the smelter mainly by rail. The scheme involves the further development of new mines, new railways and roads to provide access and to replace those submerged, a new port to handle the subsequent trade, and new houses. In addition to producing hydro-electric power, the dam would even out seasonal variations and reduce the frequency of normal floods, as well as reducing the magnitude of abnormal floods. The power would be conveyed at 165 kV. to the smelter at Kpong, which is some 16 miles away. The works would be some 34 miles from the port of Tema, and the bauxite mines are approximately 200 miles from the smelter.

CANADA : In Canada, the Aluminum Company of Canada has commenced further expansion of its capacity and, with its Kitimat scheme in operation and its Quebec plants which include the world's largest smelter, its position as the world's greatest exporter of aluminium should be easily maintained.

The great Kemano/Kitimat scheme in British Columbia came into operation in August 1954, when His Royal Highness the Duke of Edinburgh saw the pouring of the first ingot. It has already reached a capacity of 160,000 tons per annum and a further 30,000 tons per annum is planned for 1957. This increase will be followed by a further 60,000 tons in 1958 and 1959. The ultimate capacity will thus become 310,000 tons, which will require about 1·2 million h.p. Plans are already being discussed for a still further increase in capacity at the Kitimat smelter, until ultimately it may be responsible for well over 500,000 tons per annum.

The Company commenced smelting operations less than 30 years ago, in Quebec, and the installed capacity there amounts now to more than 500,000 tons, made up as follows :—

Arvida	328,300 tons
Beauharnois	33,500 tons
Isle Maligne	84,300 tons
Shawinigan Falls	61,600 tons

An additional 22,000 tons capacity is already in hand at the Isle Maligne works, and this will bring the Quebec production figure up to 582,000 tons in the immediate future.

A further three-year development project was recently begun on the Peribonka River, at Chute des Passes, to add a further 600,000–800,000 h.p. The new power plant will be sited a few miles below the existing storage dam at Pas Dangereuse, which is responsible for one of the main storage reservoirs of the Company. An intake tunnel, six miles long, is to be constructed from the reservoir to give a gross head of 636 ft. at the underground generating station. It is of interest to recall that the waters of this river, of Lake St. John, of the Saguenay River and of Shawinigan Falls are eventually used six or seven times over for power production for aluminium smelting. The power available ultimately will permit a further 210,000 tons of aluminium to be produced annually, and the new smelter is expected to begin operating before 1960. The total capacity of the Company in Canada will thus be approximately 1 million tons per annum by that time.

It must be remembered also that Aluminium, Ltd., has an international interest in the production of virgin aluminium, and has participated in the development of smelters in Scandinavia, Italy, India, Japan, Brazil and other parts of the world. It is also interested in the Volta River scheme and, in addition, has fabricating and other companies in more than 20 countries. Its bauxite mines in Jamaica are regarded as a model development project, and alumina produced on the island is transported to Kitimat. Jamaican bauxite requires treatment rather different from that of Guiana bauxite, and 50% more must be handled, but the alumina plant which started production only in 1953, already produces about 250,000 tons per annum. Extensions to this plant now in progress will raise its capacity to well over half a million tons per annum in the immediate future. The West African interests of Aluminium, Ltd., have hitherto been largely bauxite mining, but an extension of these interests is under consideration, including the possibility of a smelter drawing power from the Konkoura River.

Fabrication of semi-finished aluminium products in Canada is relatively small, so that Aluminium, Ltd., relies very largely on exports for its metal sales. Some 40% of the total output was sold in the U.S.A. in 1956, and over the previous five years it averaged over 30%. Almost the same amount is exported from Canada to to Britain annually.

The Company has, of course, major fabricating plants in the U.K., and has either planned or brought into operation during the past year new equipment in South Africa, Spain, Japan, Brazil and Uruguay.

AUSTRALIA : Australia has been a considerable fabricator and user of aluminium for many years, but its first virgin metal smelter came into production only in September 1955, when the Bell Bay Plant was opened on the River Tamar in Northern Tasmania. This project of the Australian Production Commission was undertaken in association with the British Aluminium Company as technical consultant. The site facilities and plant were brought into operation in less than five years, with an initial production rate of 13,000 tons per annum ; there is a possibility of doubling this in future. Bauxite is largely imported from Malaya to a new deep water port, and power is supplied by the Tasmanian Hydro-Electric Commission. Alternating current is rectified in plant which was originally installed in the works of the British Aluminium Company at Port Tennant, Swansea, and was re-erected at the new smelter in 1953. At Bell Bay, aluminium is reduced in 144 Soderberg furnaces, each of 140,000 amp. capacity, and the carbon paste for the electrodes is made in a plant on the site. There has had to be developed a new housing estate at George Town, 3 miles from Bell Bay, where there was originally a population of 350, and already the Tasmanian Government has built 350 houses for employees of Australia's first aluminium smelting industry.

The discovery of great new deposits of bauxite in Queensland was announced in August 1956, and more recently it has been reported that a new smelter comparable with some of the worlds largest projects may be established there. The British Aluminium Company and the Consolidated Zinc Corporation are interested in the project and The Commonwealth Aluminium Corporation has been formed. These bauxite deposits may be smelted with power which might well be generated in New Guinea, which has good hydro-electric potentialities as yet untapped.

UNITED STATES : By the end of 1955, productive capacity of American smelters was over 1·5 million tons, and by the end of 1956 it exceeded 1·65 million tons. By 1960, the U.S.A. should be producing over 2·2 million tons of virgin aluminium per annum, or some 43% of the world total.

The Aluminum Company of America, which had the monopoly of aluminium production until the second World War, is extending its existing plants in Texas and the State of Washington to increase the annual capacity of these plants by amounts reported as 78,000–86,000 tons. It is also building a new reduction works to produce 150,000 tons per annum at Evansville, Indiana, for which the 375,000 kW. required will be generated in a steam power-plant, fired by coal. By early 1958, the Company will be producing well over 800,000 tons of metal per annum.

The Reynolds Metal Company is building a new reduction plant of 100,000 tons capacity alongside its original Lister Hill works in Alabama. This plant is also being expanded by 20,000 tons per annum so that the Company will have a capacity exceeding 570,000 tons by the end of 1957. It is particularly interesting that the new Lister Hill plant will supply molten metal in special trucks directly to a die-casting foundry built by the Ford Motor Company on an adjoining site. This is one of the most significant pointers to future development that has yet been made public.

The Kaiser Aluminum and Chemical Corporation is planning a larger proportionate increase than the other big American producers, to raise its current annual capacity of 400,000 tons to nearly 600,000 tons. A new smelter is being built at Ravenswood, West Virginia on the Iowa River, to use power from a coal-fired plant. The initial capacity of 125,000 tons can be expanded to over 200,000 tons per annum later. This Company is also expanding its gas-powered reduction plant in Louisiana by 27,000 tons, so that by the end of 1958 the capacity may well be over 650,000 tons. A new alumina plant is being built in Louisiana, whence the oxide will be transported to Ravenswood by barge along the Iowa River.

There are three newcomers to the aluminium smelting industry in the U.S.A., namely, Anaconda Aluminum Company, The Olin Mathison Chemical Corporation and Harvey Machine Company. The Anaconda Company should have over 50,000 tons of capacity in operation immediately, and is planning its $1,000,000 works to produce alumina from clay. Olin is working in association with the Revere Copper and Brass Company and has under construction a plant at Clarington in the Iowa Valley to come into operation in about 12 months time. Initial annual capacity will be over 50,000 tons, with an ultimate output of 180,000 tons, using coal-fired power, and again the Iowa River will be used to convey alumina from the processing works in Louisiana, which will use bauxite from Surinam.

The Harvey Machine Company is planning to undertake aluminium reduction at Dallas in Oregon, using power supplied by the Bonneville Power Administration, and alumina to be imported from Japan. Initial output will be approximately 50,000 tons per annum, which can be increased by a further 13,000 tons.

It is very significant that two of the three newcomers to aluminium smelting in the U.S.A. are already associated with the heavy non-ferrous metal industries.

FRANCE : French aluminium production has increased since the war to 149,000 metric tons in 1956, compared with 129,000 in 1955, and France now ranks as a major exporter of virgin metal. By 1958, a total home output of 160,000 tons may be attained by the two producers, Péchiney and Ugine, but power difficulties will prevent any further substantial increases.

The most important French development, however, is the proposal to use their resources in French West Africa and the Cameroons, where two companies are expanding aluminium production in two stages. Initially, studies were made by the African Company for Research and Study of Aluminium (SAREPA), set-up by Péchiney and Ugine. The reports were favourable, and two other companies are now developing the scheme, namely, Energie Electrique du Cameroon (ENELCAM), and the Cameroon Aluminium Company (ALUCAM). The Edea Falls are being harnessed in two stages to give an output of 125,000 kW., and the reduction works will be near to the power station. In the first stage, 45,000 tons of aluminium per annum will be produced, and the plan, undertaken some two years ago, should be completed by the summer of 1958, with aluminium production commencing in the immediate future at the rate of 10,000 tons per annum.

GERMANY : German aluminium production has increased steadily since the immediate post-war period, and the total in 1956 was about 145,000 tons. Even this was not sufficient for the fabricating side of the industry, and aluminium ingot was imported, principally from Canada. Power resources which are derived from coal, will limit the amount of aluminium which can be produced in Germany in future.

NORWAY : There has always been a flourishing aluminium smelting industry in Norway, and early in 1956 two new smelters were started up to give an annual capacity of some 88,000 tons per annum. Recently, Parliamentary sanction was given for a new reduction plant at Mosjoen, with a capacity in 1958 of 20,000 tons per annum, which could be increased some three times in due course. This new venture will cost at least £7·5 million, financed by the Norwegian Elektrokenisk A/S (two-thirds) and the Swiss A.I.A.G. (one-third). It is expected that further expansion will take place, and that exports from Norway will reach 100,000 tons per annum within a very few years, thus confirming Norway as one of the most important producers and exporters of aluminium in the world.

ITALY : Italian production of aluminium has increased more than tenfold to 67,000 tons since 1946 and had exceeded the pre-war and wartime peaks by 1951. Consumption has also exceeded the 1942 maximum, and previous total output figures for both bauxite and alumina have been surpassed. Virgin aluminium

is smelted by the Montecatini Group at two sites, Mori and Bolgano, totalling about 33,000 tons per annum; by an A.I.A.G. associate—S.A.V.A.—with an annual output of over 20,000 tons, and by a subsidiary of Aluminium, Ltd., at Borgofranco producing 4,000 tons a year. Recently, Montecatini has proposed increasing its Bolgano smelter capacity to 40,000 tons per annum and has also planned a new reduction plant at Crotone in S. Italy to produce an additional 12,000 tons.

BELGIUM: Belgium has hitherto been almost exclusively an importer of both ingot and semi-finished aluminium products, but in the second half of 1956 there was considerable activity resulting in the formation of a Belgian Aluminium Syndicate with a capital of 250 million Belgian francs. A number of industrial and financial interests are concerned in this proposal, which envisages the establishment of a reduction plant in the Belgian Congo in close collaboration with the Government's hydro-electric scheme in that area.

INDIA: Production of aluminium in India will be doubled in the near future. In particular, the Indian Aluminium Company, in which there is a major Canadian holding, will bring into operation in two stages a new 22,000 tons per annum smelter at Hirakud, of which the first stage will be in operation by mid-1957. It is understood that the Soviet Union is also anxious to help aluminium production in India.

JAPAN and FORMOSA: Japanese aluminium production has increased greatly during the past few years, and outputs of more than 65,000 tons of aluminium and of 166,000 tons of alumina were planned for 1956. These figures represent, respectively, 15% and 8% increase over the previous year, and the Nippon Light Metal Association has announced its intention to produce 80,000 tons of primary aluminium in 1957. In addition, there is a flourishing fabricating and secondary metal industry in the country. The small aluminium producers in Formosa are active, and have exported a certain amount of metal during recent periods of shortage.

RUSSIA: Russia has greatly developed her aluminium production, and it is reported that the world's largest aluminium plant is now being built at Krasnoyarsk, in Siberia—in which case it must be bigger than Canada's 360,000 ton plant at Arvida. It is stated that the metal will be produced from nepheline, which will be concentrated at Achinsk. It is to be in production by 1959, and three further aluminium plants are planned for Siberia. Aluminium production in the Karelo-Finnish Republic is also to be increased by a factor of approximately 1·6. In the sixth Five-Year-Plan, there is to be a 20% increase in aluminium production, and a 40% increase in bauxite mining, whilst other reports have stated that aluminium production is to be doubled by 1960. It is not, however, expected by some experts that Russia and the satellite countries will reach more than 15–18 or perhaps 20% of world production by 1960, i.e., approximately the same as the percentage Canadian production at that time. The total output today is variously estimated at 390,000 to 500,000 tons.

HUNGARY AND EAST GERMANY: Hungary, a major producer of bauxite, has increased its aluminium smelting capacity since 1946 to some 40,000 tons per annum—about ten times the immediate post war figure. Primary aluminium production in East Germany is probably at about half the Hungarian figure, i.e. up to 20,000 tons annually.

JUGOSLAVIA; Although Jugoslavia ranges third in European bauxite output it has had virtually no aluminium ingot production until recently. From a few thousand tons in 1950-54 there has been an increase up to more than 10,000 tons in the years 1955/56 and there are now plans for a major development in using the natural resources of bauxite and the abundant water power available. The plant of Boris Kidric at Kidricevo, near Maribar, began production at the end of 1954 with a capacity of 15,000 tons a year and produced 8,500 tons of aluminium in 1956. It has been reported that its production should rise to 30,000 tons in 1958. The Lasovazzo plant at Sebenico has a capacity of 3,500 tons a year and there is a third under construction at Razina, also in the neighbourhood of Sebenico, with a capacity of about the same. Output, therefore, within the next 2 or 3 years could reach about 37,000 tons annually, but plans are afoot to increase this to 50,000 tons a year, and ultimately to perhaps 200,000 tons a year, with the help of Russia and East Germany. Immediately, it appears that a long-term loan by the Russian and E. German Governments equivalent to 700 million roubles will be made to bring into effect new plant by 1961, the output of which will be used to repay the loan. It is apparent that there is also to be an increase in the conversion of ingot to semi-fabricated products.

SOUTH AMERICA: Although South America is one of the principal sources of bauxite, there has hitherto been little production of aluminium there, but it is natural that there should now be considerable effort directed towards reducing the metal from the ore on site. Hydro-electric potentialities have recently been studied, and negotiations initiated between the Dutch Guiana authorities and N. American concerns on a project to dam the Surinam River at Brokopondo. Up to 20,000 tons of aluminium may be smelted near the ore beds, and among the groups interested are Alcoa, The Kennecott Copper Corporation and Reynolds Metals Company.

The Argentine, Brazil and Venezuela are among the S. American republics interested in aluminium potentialities, all having useful hydro-electric potentialities.

Developments of Usage

With the possibility that for the first time for many years there will be, in 1960, a world excess of production over consumption, by as much as a million tons,[5] it is obvious that much effort must continue to be concentrated on development of new uses. It is significant in this respect that during 1953/4 the O.E.E.C. investigated possible competition between aluminium and steel, with a supplementary Report two years later.[6] Whilst the aluminium industry can, by no means, accept all the conclusions of these Reports the fact that they have been issued at all is significant. In many fields of use, aluminium will compete largely with other non-ferrous metals, but the most spectacular increases may be expected where aluminium competes with steel for such items as roofing sheets and the cladding of buildings. In transportation, the lower weight of aluminium compared with steel already makes it extremely competitive, taking into account savings in fuel and maintenance. It is likely to make increasing inroads into heavier materials of construction due to the ever increasing importance of conserving fuel and power. It is becoming firmly established, not only for road

TABLE V.—APPROXIMATE ANALYSIS OF END USES OF ALUMINIUM IN THE U.K. 1955/6.

Application	Percentage
Direct Exports	13
Road and Rail Transport	23
Domestic and Office Equipment	9½
Packaging	8
Electrical Engineering	7½
Building and Structural Engineering	7½
General Engineering	6½
Chemical Plant	1
Destructive Uses	7
Miscellaneous, Stockist Sales, etc.	17
	100

vehicles, which already consume more than 20% of the output of most industrial countries, but also for railways and ships—two traditional industries which must be very firmly convinced of the case for a change before any large scale acceptance is possible. The high capital cost and long service life of both ships and railway equipment also militate against the adoption of aluminium until it has been fully proved, but such proof is now forthcoming from actual experience, and the future holds out most attractive possibilities for increasing aluminium usage many fold in these fields.

It is also significant in the international field that there is increasing co-operation on new uses, such as through the European organisation, Centre International de Developpement de l'Aluminium (C.I.D.A.) and through the standardisation work of the I.S.O. and the I.E.C.

The British Position

The future of aluminium utilisation in the U.K. must be considered in two related parts, namely, the immediate possibilities and the long-term developments. Some end use figures are given in Table V and these are of interest in relation to the figures for semi-fabricated forms of aluminium in the U.K. set out in Table VI.

In the short-term, the industry's future is less assured than might be expected from a case based on technical considerations only. Thus, the effects of the credit squeeze on sales of motor cars, domestic equipment and many other consumer goods are being felt by the material producers. Sales of aluminium in these fields are therefore becoming more difficult, and the higher rates of interest are militating against, or slowing down, some types of building and constructional work, which again may have an effect on aluminium usage.

On the other hand, current difficulties arising from fuel shortage are undoubtedly making users of vehicles more conscious of the value of aluminium for power economy. In particular, the shortage of petrol and diesel oil makes economy of operation of greater importance, and it is being more generally realised that a reduction of 30–50% in the bodyweight of road and rail vehicles is possible by the use of aluminium which, in turn, may reduce fuel consumption by 12–20%. The rather higher initial cost of aluminium over steel for vehicles should be readily absorbed in a year or so of moderate running, due to lower fuel consumption

TABLE VI.—DESPATCHES OF SEMI-FABRICATED ALUMINIUM AND ALUMINIUM ALLOYS FROM U.K. MANUFACTURERS IN 1955.

Form	Tonnage
Rolled Plate, Sheet, Strip and Foil	144,203
Extruded and Drawn Products	73,758
Forgings	5,294
Castings	90,206
Small Users, Unidentified Castings, etc.	10,000 approx.
Destructive Uses	21,000 approx.

TABLE VII.—ANNUAL PER CAPITA CONSUMPTION OF ALUMINIUM.

Country	lb. per head	Country	lb. per head
U.S.A.	22	Australia	5
Britain	15	Italy	5
Switzerland	14	Eire	2
Canada	12	Japan	1
W. Germany	11	Jugoslavia	1
Sweden	9	Spain	1
Austria	9	S. Africa	1
France	7	Greece	0·4
Norway	7	India	0·1

coupled with better acceleration and reduced maintenance.

It may be noted that successful operation of aluminium coaches on London Underground includes not only a saving of over 12½% in power required, but also lower maintenance due to freedom from rusting. Following London's example, the new Toronto Subway is trying out unpainted aluminium cars, which have shown also substantial economies in brake shoe wear. British Railways have more than 200 light alloy diesel cars in service and more are now envisaged.

A pointer to large scale usage at sea is the decision of the Orient Line to build a new 40,000 ton ship for the Australia run with about 1,000 tons of aluminium in its superstructure. It will carry 2,000 passengers to Australia in three weeks at 27 knots, and the use of aluminium will permit an additional 150 first-class passengers to be accommodated. Its sister company the P. & O. Line has just announced that its new 45,000 ton liner to be built at Belfast will have an aluminium superstructure of some 800 tons, both gratifying results of the long term researches in this field.

Shortage of fuel oil for heating and the continuing stringency of solid fuel underlines the value of thermal insulation for buildings, and the use of aluminium foil for this purpose should be greatly developed. Aluminium roofing sheets and side cladding also contribute to reducing heat losses by radiation from buildings, and even when the surface is somewhat dulled by exposure, appreciable conservation of heat is still achieved.

Changes in the shopping habits of the population due to self-service stores will be reflected in the wider adoption of aluminium for packaging—already a very substantial end use of aluminium foil, collapsible tubes and containers.

Technical problems are being solved—for example, finishes for building applications—and specifications are being prepared to ensure the earliest possible adoption of research results—e.g., a standard for aluminium motor car trim has been drafted for tentative use. Incidentally this development highlights a possible extension in the use of super-purity metal (99·99% aluminium), the world output of which has substantially increased in the past year.

These and many other trends indicate that the future of aluminium will be one of almost continuous expansion. Cost, of course, always proves the final factor in the utilisation of any material, but there is an increasing realisation by designers and users of the overall economic advantages of aluminium, taking into account such long-term savings as fuel and maintenance, plus higher scrap values, in relation to first cost. The general policy of the world aluminium industry has been to keep the price of ingot at the lowest practicable cost with maximum stability. The price of aluminium in Britain is lower than elsewhere in the world, but it must be

(*Continued on page 90*)

The Effects of Lubricants on the Surface Appearance of Aluminium after Plastic Deformation

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The effect of lubricants on the surface finish of products after metal forming operations is a subject which has received some attention of recent years. This problem is discussed briefly in this article, and the results of some simple experiments are presented to show how variation of viscosity of lubricants containing no additives may influence the surface condition of aluminium in compression.

DURING work previously carried out to determine the constrained compressive-yield-stress/strain curve of annealed aluminium strip, using the plane strain technique due to Ford,[1] the author used various lubricants between the strip and indenting platens in an attempt to reduce friction to the practical minimum. Whilst several satisfactory lubricants were found for this purpose, it became evident whilst testing that the nature of the lubricant used influenced greatly the surface appearance of the strip after deformation. It was found possible to select a lubricant giving a lustrous or matt surface appearance, almost at will.

Initially, there appeared to be little relationship between the lubricant properties, the type of surface effect produced, and the yield stress curve (which indicates indirectly the friction conditions at the interface), other than the fact that, in general, the higher the lubricant viscosity the more matt the deformed strip surface appeared to become. The realisation that the presence of boundary additives (even in small percentage additions to the parent lubricants) might provide some confusion led to further tests using a series of straight mineral oils containing no additives. These indicated that, with such lubricants, increasing viscosity was associated with deteriorating surface lustre and also with the reduction of frictional resistance at the tool-to-metal interface. The presence of boundary additives appeared to modify the basic relationship between viscosity and friction conditions, inasmuch as their introduction in small percentages into a low viscosity base oil, whilst not substantially affecting the lubricant viscosity, and therefore the surface finish associated with it, did modify the metallic surface films, resulting in much lower friction than was experienced with the base oil alone.

The effect of lubricants on the surface appearance of metals during forming operations has received considerable attention of recent years, and was discussed at some length during the Institution of Petroleum Symposium on Metal Working Oils in 1954. Here, Ford, when discussing the results of friction measurements during the cold rolling of aluminium sheet, stated that lubricants giving a low coefficient of friction left the sheet surface matt and dull. During the discussion, the present author, referring to this point, suggested that this statement was not complete without reference to the physical properties of the lubricant, and that the primary cause of the resulting matt appearance was not so much related directly to the low coefficient of friction at the interface, as to

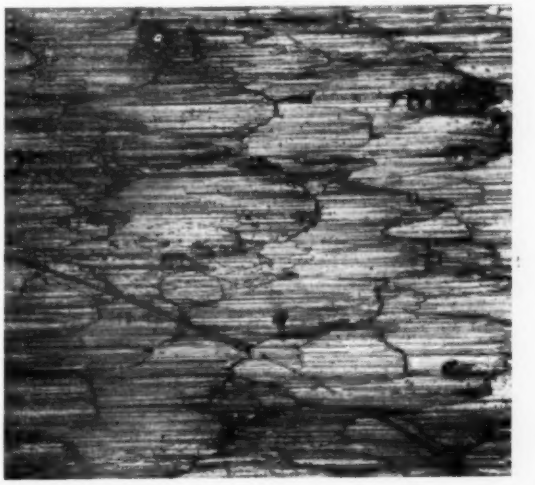


Fig. 1.—Noral 2S hot mill strip (¾H). Surface as rolled × 100

the thickness of the lubricant film present, which in turn would influence the frictional resistance.

This argument has been developed by the author in considerable detail in a recent series of articles,[2] the main relevant point here being that, if the entrapped lubricant film were relatively thick, i.e., of the same order as the surface irregularities of the tool and metal, deformation could occur via the hydrostatic pressure transmitted by trapped lubricant. In such case, burnishing of the metal surface would be substantially avoided, the final surface appearance being to a large extent governed by the metallurgical structure and mechanical properties of the metal. Further, the frictional resistance between tool and metal would in part be the result of the shearing of any intimate tool-to-metal surface junctions formed, and in part the shearing of the trapped lubricant under the current conditions of pressure and temperature. This would result in reduced friction by comparison with the interface conditions likely to give overall burnishing.

Some further experiments have now been carried out which illustrate the effect of surface deterioration under various conditions of lubrication.

Simple compression tests were conducted on sheet specimens, approximately ½ in. square × 0·140 in. thick, in aluminium alloy to specification B.S. 1470 SIC

Fig. 2

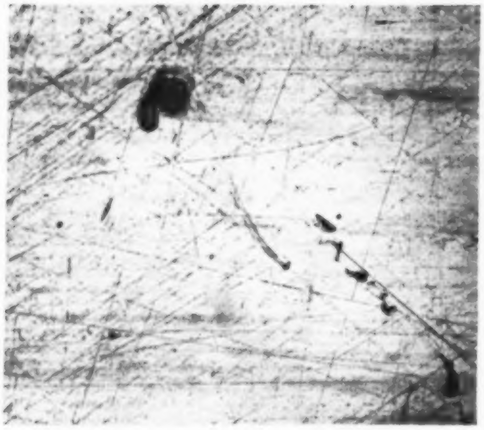


Fig. 3

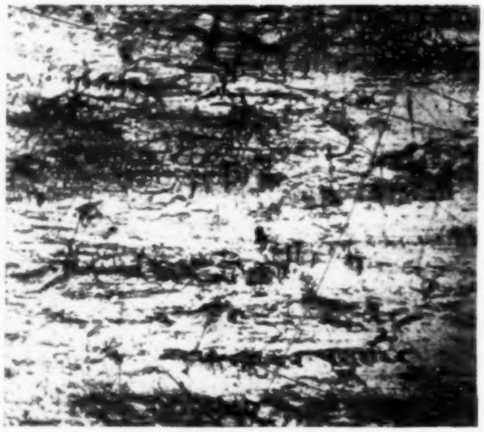


Fig. 4

Fig. 5

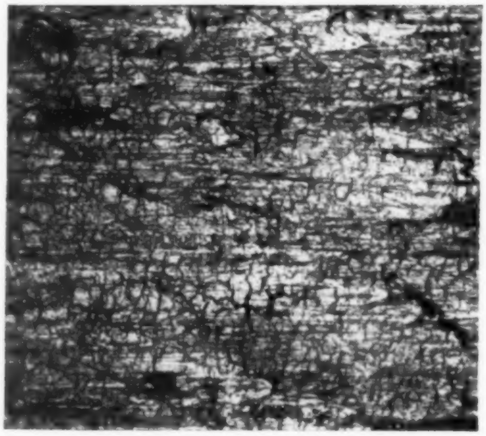


Fig. 6

Fig. 7

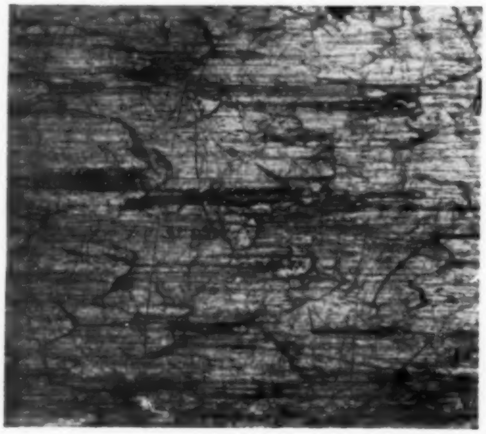


Fig. 2.—Noral 2S hot mill strip (¾H). Compressed approximately 11%. No lubricant. × 100

Fig. 3.—Noral 2S hot mill strip (¾H). Compressed approximately 29%. Lubricant viscosity 31·8 centistokes at 100° F. × 100

Fig. 4.—Noral 2S hot mill strip (¾H). Compressed approximately 29%. Lubricant viscosity 820 centistokes at 100° F. × 100

Fig. 5.—Noral 2S hot mill strip (¾H). Compressed approximately 29%. Lubricant viscosity 50 centistokes at 210° F. × 100

Fig. 6.—Noral 2S hot mill strip (¾H). Compressed approximately 29%. No Lubricant. × 100

Fig. 7.—Noral 2S–O. Compressed approximately 7%. Lubricant viscosity 50 centistokes at 210° F. × 100

Fig. 8

Fig. 9

Fig. 10

Fig. 11

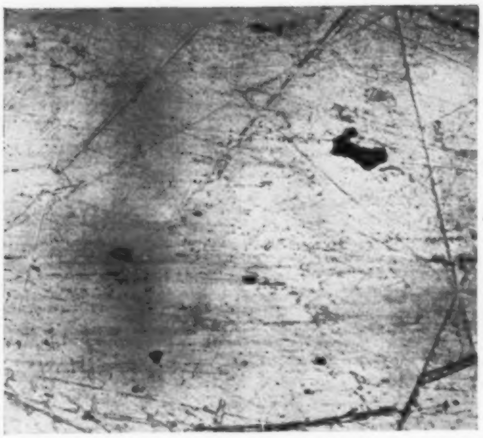


Fig. 12

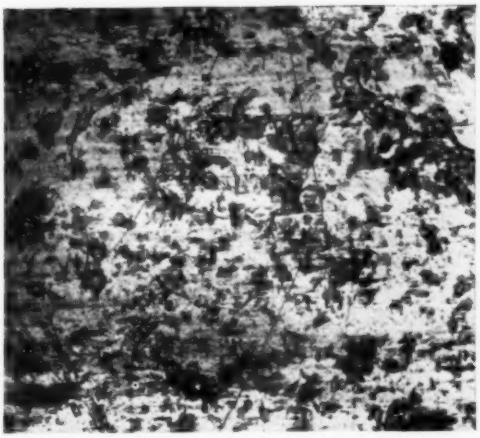


Fig. 13

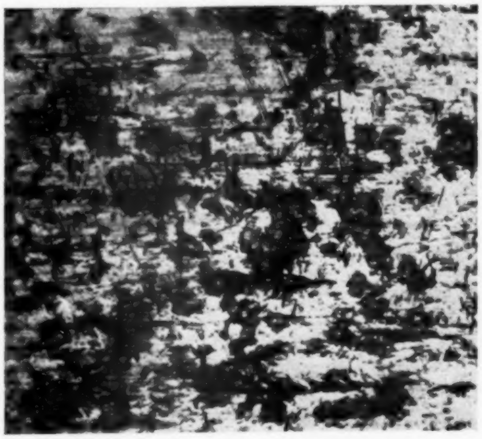


Fig. 8.—Noral 2S–O. Compressed approximately 15%. Lubricant viscosity 50 centistokes at 210° F. × 100

Fig. 9.—Noral 2S–O. Compressed approximately 28%. Lubricant viscosity 50 centistokes at 210° F. × 100

Fig. 10.—Noral 2S–O. Compressed approximately 73%. Lubricant viscosity 50 centistokes at 210° F. × 100

Fig. 11.—Noral 2S–O. Compressed approximately 28%. No lubricant. × 100

Fig. 12.—Noral 2S–O. Compressed approximately 28%. Lubricant viscosity 31·8 centistokes at 100° F. × 100

Fig. 13.—Noral 2S–O. Compressed approximately 28%. Lubricant viscosity 173.9 centistokes at 100° F. × 100

(Noral 2S), as received after hot rolling (therefore in a workhardened condition—approximately $\frac{3}{4}$H) and also after annealing (Noral 2S–O). The steel compression pads which completely overlapped the specimens were highly polished, and the pads and specimens were cleaned with acetone before each test, prior to applying a lubricant selected from a series of paraffinic base oils containing no additives, and of widely varying viscosities. The percentage compression of each specimen and the load applied in each case were recorded, and photographs taken of representative fields of the deformed surfaces. Vertical illumination was used, and the magnification was 100. Some of these photographs are reproduced in Figs. 1–13.

Fig. 1, showing the surface appearance of the sheet as received from the hot mill ($\frac{3}{4}$H), reveals clearly the longitudinal score marks and wave-like appearance characteristic of this sheet, resulting from the rolling operation. To the eye, this appears quite dull and non reflective. After applying a 10,000 lb. load without lubricant (giving 11% compression), Fig. 2 shows the sheet surface to be quite smooth and free from defects, appearing visually highly polished. Figs. 3, 4 and 5, show the same material, again after 10,000 lb. applied load but with lubricants of increasing viscosity. The percentage compressions are considerably greater in each case (approximately 29%), and the surface conditions deteriorate as the lubricant viscosity increases, until to the eye it is less reflective than the original sheet. The same amount of compression however (29%) without a lubricant, although requiring increased load, again results in a highly polished surface (Fig. 6).

Figs. 7–13 show the appearance of the annealed material (Noral 2S–O), after deformation. Figs. 7–10 form a series illustrating the effects of increasing deformation with the heaviest lubricant and illustrate the progressive deterioration of the surface. Fig. 7 (7% compression) shows the original surface structure almost undisturbed, but with evidence of occasional tool-to-metal contact. In Fig. 8 (15% compression) the original surface structure is still just apparent, although now becoming confused by other random surface effects. In Figs. 9 and 10 (28% and 73% compression, respectively) the original surface structure is completely masked by random deformation of the surface, with discrete areas of tool-to-metal contact.

Figs. 11–13 are comparable with Fig. 9, inasmuch as they represent specimens compressed the same amount i.e., approximately 28%. The specimen in Fig. 11 was unlubricated, whilst those in Figs. 12 and 13 were lubricated with oils of lower viscosities than the specimen in Fig. 9. They show surface deterioration, but not so esvere as that obtained with the higher viscosity lubricant.

Thus, it can be seen that with the material in the work hardened or annealed condition, compression without, or with a very light, lubricant results in a highly polished surface appearance which can be an improvement over that of the original stock, and which depends largely on the surface condition of the tool, since the deformed surface virtually becomes a replica of the tool surface. With increasing lubricant viscosity, however, the surface appearance deteriorates rapidly, and may result in an overall matt effect, visually far worse than the original stock appearance.

It is apparent that the causes of the deterioration are not precisely the same in the annealed material as in the work hardened. The photographs of the latter material show the presence of what appear to be microscopic surface cracks, whilst the annealed material, during its progressive deformation, appears to deform inhomogenously, possibly due to the varying orientations of the crystals, or by slip within the crystals, or by a combination of both. It is likely that the ductility of the harder material is sufficiently low that the lateral surface strains induced by the normal compression are sufficient to cause surface fissures, which are penetrated by the lubricant and subsequently aggravated. Typical mechanical property figures of the material in the two conditions show the percentage elengations on 2 in. gauge length to be 5% and 30% for Noral 2S–$\frac{3}{4}$H, and Noral 2S–O, respectively.

Acknowledgment

The author wishes to thank C. C. Wakefield & Co. Ltd. for the supply of lubricants and details thereof.

REFERENCES

1 Ford H. *Proc. I. Mech. E.*, 1948, **159**, 115.
2 Butler L. H. *Sheet Metal Industries*, 1956, **33**, (352), 571 ; (353), 647 ; (354), 727.

The P. T. Oxygen Gun

It is announced that The Steel Company of Wales, Ltd., has concluded an agreement with Kaiser Engineers, of Oakland, California, in connection with the P. T. Oxygen Gun. This agreement grants to Kaiser Engineers the right to make, use, sell and sub-license to others the oxygen gun equipment which has been patented in this country by the Steel Company of Wales. The rights granted to Kaiser Engineers apply throughout the world, with the exception of Europe.

The P. T. Oxygen Gun has been developed by the Steel Company of Wales for use in open hearth furnaces for rapid carbon elimination by jet impingement of oxygen on to the surface of the steel by means of a gun centrally mounted through the furnace roof. Particularly suitable for big open hearth shops with fixed furnaces and ground chargers, the gun is in regular use on all the furnaces in the Abbey Works melting shop at Margam. The advantages of the gun over other methods are numerous. In particular, the operation of the gun can be fully mechanised and, in addition, there is no interference with charging or tapping operations as occurs when a lance is inserted in the front or back of the furnace. More than 60,000 cu. ft./hr. of oxygen can be delivered to the furnace, greatly increasing the rate of carbon removal in the lower carbon ranges. The subsequent decrease in the tap-to-tap time considerably increases steel production.

Sir William J. Larke Medal

The Council of the Institute of Welding has awarded the Sir William J. Larke Medal for 1956 to Dr. D. C. Moore and Mr. E. A. Taylor of Imperial Chemical Industries, Ltd., for their paper on "The Welding of Copper and Copper Alloys." The following papers received honourable mention by the examiners : "Some Electrical Aspects of Inert-Gas Shielded Arc Welding," by Dr. L. H. Orton and Mr. J. C. Needham ; "Resistance Welding and Post-Heat-Treatment of Steel Stud Projection Welds," by Mr. E. V. Beatson, Mr. E. Mitchell and Mr. L. N. Sayer ; "Strains in Flanged Pipes," by Mr. J. Y. Davies and Mr. E. J. Heeley ; and "The Composition of Weld Metal," by Mr. W. P. Van der Blink.

Aluminium and its Alloys in 1956

Some Aspects of Research and Technical Progress Reported

By E. Elliott, A.Met., F.I.M.

Senior Metallurgist, Aluminium Development Association.

Attention is drawn to work published in this country and the U.S.A., reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution, properties and standardisation. Reference is also made to interesting applications of these materials.

THE year 1956 was noteworthy as having one of the worst summers within living memory, but that is common to four out of every five English years. Perhaps the events for which the year will be most remembered were those occurring in the Middle East, and the consequent return of that bane of the existence of the entire community, petrol rationing. After deploring, as only he can, the vagaries of the automobile, Thurber[1] has as the last sentence of one of his "short pieces" the words "If the worst comes to the worst, I could even walk." So could we all, but none of us wants to, and the immediate concentration of the motor and motor-cycle advertisements on mileage per gallon has been almost unanimous. This is something that the aluminium industry has been preaching for years, not without success; lighten your steed, and your speed will be greater and your cost per mile lower. The present stringencies should drive this further home.

Thomas[2] has looked at aluminium both historically and economically, and shown how it fits into the country's industrial life. He notes how vital the metal has become in a variety of end-uses, and points to those where future development seems most likely to be rapid.

Production

The extraction of aluminium from the ore is largely performed in places remote from established centres of population, and the aluminium smelter at Bell Bay in Tasmania is no exception to this rule. It is not often realised that until the opening of this plant in 1955 the production of virgin aluminium was confined to the Northern hemisphere, and a recent article[3] has made clear the importance of this project to the industrial potential of Australia. Superlatives are usual in descriptions of aluminium smelters, and at Bell Bay the rectifying plant, previously installed at Port Tennant, Swansea, is the largest south of the equator.

France is the cradle of aluminium, and a French town gave its name to the ore commercially used for production of the metal, namely bauxite. The present position of the French aluminium industry has been described.[4] The statistical information given is impressive, showing the truly phenomenal increases over the past 45 years in output of both bauxite and virgin metal; at present, France is a close second to Germany as the largest aluminium producer in Europe. One of the difficulties facing the French aluminium industry is the high cost of its electric power, and this has caused it to embark on an ambitious development[5] in the French-mandated Cameroon, south of the Sahara desert, harnessing the waters of the Sanagha river. The contemplated metal output is 45,000 tons yearly, later to be increased to 100,000 tons. The account of this new venture also refers to possible greater projects in French Guinea, where exist together hydro-electric potentialities and large deposits of bauxite, providing that devoutly-to-be wished consummation of all aluminium companies. Such conditions obtain in the Gold Coast by the Volta river, and the middle of the year saw the issue of the very large three-volume report[6] of the Commission engaged in assessing the possibilities of establishing there an aluminium extraction industry. The engineering aspects seem to be satisfactory, but the political dangers are frankly set forth. These, together with the fact that the estimated cost has risen from 140 to 230 million pounds must give rise to very careful thought; on the other hand, the scheme, if successful, would save the sterling area 35 million pounds worth of dollars yearly.

Increases in the world supply of virgin aluminium are so regular as to approach the commonplace, but they must be supplemented by ingot produced to standard specifications by the industry devoted to the reclamation of scrap. The handling of these ingots presents problems, and the methods adopted by two companies to simplify this task have been described.[7, 8] Steel strapping is used and bundles of ingots are moved by fork truck. Thus by the application of careful design and mechanical handling the labour engaged in storing and delivering ingots is reduced to a minimum.

Melting and Casting

As mentioned above, petrol rationing has had incalculable effects on the country's economy, and not least on the sales of motor vehicles, and the road transport industry is easily the largest single user of aluminium alloy castings. A drop in its demand is therefore a challenge to the founder to develop other applications, and increase in efficiency leading to reductions in price, or maintenance of existing prices in face of a steadily advancing general price level, are his chief weapons. Sawers[9] has described the operations in his foundry producing sand and gravity die castings, and he includes numerous actual examples of the techniques employed to make individual castings. His paper brings out clearly the special difficulties facing the founder, which vary with each job, and must be met by ingenuity and that skill which can be purchased only by long experience.

Much is heard nowadays of automation, a regrettable word that has nevertheless the merit of most American importations, that everybody knows what it means and cannot replace it except by several others. An American company[10] has developed an electronically-controlled gravity die casting machine that not only takes the hard manual work out of the process, but enables an unskilled operator to attain the productivity of two skilled workers using conventional gravity die casting methods. Metal temperature is automatically controlled, pouring rate is electronically governed, and an adjustable timer returns the tilting furnace to vertical after the completion of a casting cycle. Automation is also mentioned by Millward and Partridge[11] in their general review of the melting of light alloys; they see the steady trend from sand to die casting as an example of the phenomenon, and point out that the automatic transfer by pumping of molten metal from furnace to casting position, or even from primary producer to foundry is the most significant advance that could be made, and is probably nearer realisation than is generally appreciated. Are the terms pig and remelt ingot therefore obsolescent? Surely not, until man can build a molten metal pipeline across the ocean, since although international trade in aluminium and its alloys for the manufacture of wrought products might conceivably one day be confined to billets and slabs, the foundry industry will still need a proportion of imported virgin metal.

High strength in the casting alloys currently standardised in this country may be obtained only by heat-treatment, and Dew[12] has discussed his methods of foundry control designed to produce fine-grained castings which will respond readily to solution-treatment. He refers particularly to the aluminium-copper high strength alloy (LM11 in B.S.1490), in which it is so easy to obtain properties in the casting well below those specified for test-bars, and draws attention to the dangers of "over-degassing," leading to intercrystalline shrinkage. Again, an instance of the skill and perception required of the founder, particularly when working with "difficult" alloys. There is increasing use of aluminium alloy castings in applications requiring exceptional dimensional stability, both during machining and in service, servo-mechanisms and special cameras being examples. Non-heat-treated castings may be stabilised by stress-relieving heat-treatments, but where high strength is required, the problem is greater as the effect on mechanical properties of heat-treated alloys may not be acceptable. According to Olsen,[13] an alloy of type somewhat similar to LM8-WP may be rendered exceptionally stable by a combination of treatments at elevated and sub-zero temperatures, without great loss of strength. He also claims that properties equal to those obtained by water quenching after solution-treatment may be secured by air cooling, using a cooling rate even less than that produced by an air blast. This seems contrary to the generally held view, unless the castings concerned are very small and of very thin section.

The binary aluminium-silicon alloys of eutectic composition are at once the delight and the bane of the sand founder; the modification process is one which has attracted many investigators, and still seems to be the principal part of the aluminium section of any course taken by general metallurgical students. Degassing and sodium modification are enemies; each tends to remove the effect of the other. Logan[14] claims that this problem is now solved, by making the enemies into allies in a combined process, modification and degassing being effected by plunging into the melt an aluminium can which contains degasser, and sufficient of a modification agent to persist after the degassing ceases. A single standing period of 10–15 minutes is stated to be sufficient for the whole process. No great use of the hypereutectic aluminium-silicon alloys has been made in this country, but they are popular on the Continent as piston alloys. The favoured modification element for these alloys is phosphorus, usually introduced as the pentachloride or as phosphor-copper, both of which have obvious drawbacks. According to Thury and Kessler,[15] and they support their claims by some impressive photomicrographs, mixtures of powdered aluminium and phosphorus compounds give much better results, phosphorus being distributed throughout the melt by a metallo-thermic reaction; subsequent treatment with chlorine gas gives further grain refinement. Kessler, however, this time in collaboration with Winterstein,[16] has subsequently reported that the method gave variable results, and was found to depend for its efficiency on the grain size of the refining mixture. Using a mixture of red phosphorus, potassium chloride and potassium titanium fluoride, ground to a fineness between 20 and 60μ, refinement of both eutectic and primary silicon was consistently obtained. The conclusions are supported by photomicrographs and pictures of the machined surfaces of castings.

High strength combined with high ductility in a casting are a rare combination, but are attainable with the solution-treated aluminium–10% magnesium alloy (LM10-W in B.S.1490). Naturally they are only available to the founder who can overcome the difficulties of the material; not without reason is it so often written that this alloy requires special foundry techniques. Whitaker[17] has described work on the tendency of the alloy to metal/mould reaction in sand casting, and listed the precautions to be taken, including beryllium additions to the metal, avoidance of sodium contamination, moulds rammed as hard as is consistent with adequate permeability, and lowest practicable pouring temperature. A very useful table is given of the proportions of ammonium bifluoride or boric acid that should be added to the sand as inhibitors, the quantity varying with the section thickness of the casting and the degree of porosity that is regarded as acceptable. Another well-known peculiarity of alloy LM10-W is the variable results that may be obtained on test bars from different melts, and Jay and Cibula[18] have investigated this problem. They conclude that magnesium contents over 12% give undissolved β-phase, inducing brittleness; with less than 10·8%, however, layers of micro-porosity occur, reducing tensile properties. Layer porosity is also intensified by gas content and lack of feeding. An interesting point is that a D.T.D. test bar in this alloy contains about 0·9% greater average magnesium content than the melt from which it was poured, due to the flow of magnesium-rich liquid from the feeder-head.

Hydrogen is the great enemy of aluminium and its alloys, in view of the high solubility of the gas in the molten metal, and its low solubility after solidification. Ransley and Talbot[19] have considered the available methods of measuring hydrogen content, and emphasised the advantages of the hot extraction method, especially for routine use. Gas in pores or blisters may

be extracted for analysis by a neat method involving a vacuum drill.

Although aluminium melts at a fairly low temperature, the industry is not without problems in choice of refractory. They have been reviewed by Rochow and Brashares,[20] who describe a handy laboratory test to compare refractories; pockets are cut in the brick and molten aluminium held in them for a period of 30 hours at 1,500° F.

The 1956 British Industries Fair led Smith[21] to consider generally the uses of aluminium casting alloys, and how they have varied and increased over the 40 years' history of the exhibition. He shows how rigid control and standardisation have so lifted the reputation of casting alloys, made partly or principally from remelted scrap, that today the opprobium that once attached to so-called "secondary" materials has been completely and rightly changed into full approval. Smith points to the wide choice available to the founder and castings user from the 22 alloys covered by B.S.1490; however, none of these offers high proof stress and good ductility in the as-cast condition. The aluminium-zinc-magnesium alloys have long been known for their natural age-hardening characteristics, combined with good corrosion resistance, machinability, shock resistance, and suitability for anodising; they have been regarded, however, as difficult to cast. It has been announced[22] that an alloy of this type, with an American trade name, is available in ingot form in this country, and is being used by certain founders; a D.T.D. specification has now been issued to cover this alloy.

Working

At the Supplier's Works

No revolutionary strides in the semi-fabrication of aluminium and its alloys have been reported during the year; methods for avoiding the billet stage, such as the Properzi and Rigamonte processes, are still receiving attention, and indeed being used to some extent, but traditional methods still hold the field. Sendzimir[23] has described the cluster strip-mill that bears his name, and is enjoying increasing use in both Europe and America for steel and non-ferrous metals, including aluminium and its alloys. The ease with which the work-rolls can be changed is emphasised, and the author claims that the small diameter of these rolls, by tending to eliminate the stresses in the bite, particularly near the edges, permits the rolling of aluminium-magnesium alloys with the minimum of edge-cracking.

Clad metals are nowadays in considerable volume of use for various reasons, including improvements in corrosion resistance, solderability, and appearance. Many methods of cladding are known, and now Durst[24] has announced the P.T. process, in which the bond is created by cold rolling followed by heat-treatment to give recrystallisation across the interface, a phenomenon that Durst terms sintering. Absolute cleanliness of surfaces before cold-rolling is so important that the cleaning stage is set in train with the rolls, so that only seconds elapse between cleaning and rolling. Examples of clad metals produced by this method include Aliron, steel clad with aluminium, and Alcuplate, aluminium clad with copper.

Despite the metal physicists, most of the metallurgical processes at present in use have been developed by rule of thumb and experience, and the higher mathematics usually come in later to explain what is happening. Feltham[25] has set forth his theory of extrusion, which involves some erudite equations, and has shown in a table how well his results compare with those found by experiment. He is able to evaluate extrusion pressures and also to predict optimum billet dimensions for aluminium, copper and lead. The extrusion capacity of the country has recently been considerably augmented by the installation at the works of one of the major semi-fabricating companies[26, 27] of two additional presses of 3,500 and 5,000 tons capacity, together with the necessary ancillary plant, including furnaces and heavy stretching equipment. Much aluminium was used in the building in which the presses are housed. Another company now has in full production a tube drawbench[28] capable of cold drawing over ten miles of aluminium alloy tubes per hour in lengths up to 130 ft., the whole being controlled by one man. This automatic plant is thought to be the only one of its type in the world, and produces tubes three at a time at a drawing speed of 450 ft./min.

The present tendency in aircraft construction is to replace fabricated fittings by large forgings, and Wilson[29] has discussed the problems of their manufacture in high-strength aluminium alloys, from the difficulties of casting large billets to the great care necessary in machining and heat treatment to avoid excessive internal stress. This author has carried out extensive strain-gauge measurements of internal stress in typical forgings, and his paper is particularly useful in illustrating how easily internal stresses can become sufficiently high as to cause cracking, unless special attention is paid to design, quenching procedure, and the planning of the correct order of machining and heat treatment. Larger forgings demand larger presses, and much has been heard of the press programme in the United States. An account[30] has been published of the stage reached, together with some descriptions of the operation of the 50,000 and 35,000 ton presses, and the type of component that is now being forged. The importance of avoiding internal defects in forgings and plate has led to rapid improvements in ultrasonic inspection equipment, and Vernon[31] has described the automatic scanning method, carried out with the workpiece fully immersed in water. This process is applicable to specimens of simple cross-section, and considerably increases the speed at which they may be examined.

The lubrication of dies used in the hot-working of aluminium alloys presents many problems, and these have been enumerated and discussed.[32] The advantages of graphite for high temperature lubrication are stressed, but the dangers of incorrect application are pointed out; they include particularly the possibility of hard nodular particles becoming embedded to quite considerable depths in the metal surface.

The metallurgical industries are great users of furnaces, and progress in the design and construction of preheating and heat-treatment furnaces continues apace. METALLURGIA[33] has again published its annual review of recent installations, and the examples illustrated include a preheating furnace for aluminium alloy rolling slabs, which operates at 3 tons per hour, and is highly mechanised to give easy and rapid handling of the charge.

At the Consumer's Works

Once again the Institute of Metals has held a Symposium devoted to a particular aspect of non-ferrous metal technology, the final forming and shaping of

wrought materials. Taken together, the papers represent an invaluable statement of the present position of the various arts, and a fitting termination of the series of Symposia that began with melting and casting. Much of the data in Griffin's[34] paper on cold roll-forming and press brake manipulation are concerned with aluminium, and he includes a very useful table giving minimum bend radii at different tempers and thicknesses for both work-hardening and heat-treatable alloys. Information is also presented on the bending of sections, and notes on the finishing procedure applied to aluminium alloy venetian blind slatting. Edwards[35] deals with the stretch-forming of aluminium alloy sheet and sections as employed in the aircraft industry, and reviews the types of equipment available. In an illustrated appendix, several examples of stretch-formed components are listed, together with full details of the methods used in their manufacture. Various forming methods based on bending are covered by Perry,[36] who discusses a mathematical relationship involving a strain-hardening exponent, the value of this being listed for a number of metals, including standard aluminium alloys and also two aluminium-magnesium alloys and one aluminium-copper alloy based on high purity metal. Perry considers a number of factors affecting formability and quality of ultimate product that may be revealed by careful inspection of sheet as delivered at the user's works, as, for instance, variation in hardness, surface finish and composition.

Another forming operation used mainly in the aircraft industry is rubber pressing, and a paper on this subject was contributed to the Symposium by Fielding.[37] He reviews equipment and tool design, and the deformation characteristics of the material to be formed, basing his calculations on the clad solution-treated alloy L72. One of the difficulties of rubber pressing is wrinkling, and methods are given of avoiding or reducing it. The Symposium would not have been complete without a contribution from the workers at Sheffield University, and Johnson's[38] paper gives the results of the experimental and theoretical work there on the redrawing of shells, with reference to the effects of lubrication, drawing speed, flange wrinkling and ironing. Some attention is also devoted to tube-sinking, stresses in cold-drawn tubes, impact extrusion and coining. Grainger,[39] in his paper on deep-drawing and spinning, lists the results of many applications of the Swift cupping test with varying conditions of lubrication, but these are on copper sheet. Some account is also given of techniques for producing small quantities of parts, including marforming, hydroforming, and flow-turning. Grainger concludes from tests on S.A.P. that that material has very little capacity for deep drawing.

As a final reference to the Symposium, note must be taken of the contribution from Galloway[40] on machining properties. The general aim of his paper is to illustrate how research has been applied to the solution of problems of machining the newer non-ferrous alloys, such as those based on titanium and the nickel-based creep-resisting materials, but there is some reference to tests on aluminium alloys.

In a general account of the cold-forming of aluminium alloys, Barlow[41] has presented a surprising amount of guidance in a very small space, and perhaps the most useful part of his article is a table covering almost all the standard wrought alloys and giving for each such information as maximum reduction in deep-drawing, bend radii at different thicknesses, limiting stretch in stretch flanging, maximum increase in diameter in cold riveting, and so on. All in cold figures, and quite devoid of ifs or buts, the table is ready to act as the metal former's *vade mecum*. Bucey's[42] article on metalworking advances, principally in the aircraft industry, deals largely with matters already mentioned in connection with the Institute of Metals Symposium, but from the American point of view. The author refers to the production by extrusion of integrally stiffened skins, and their subsequent "sculpturing" by chemical milling or electronically-controlled machining equipment.

Although flow-turning has been in use for an appreciable time, little has appeared in the literature about it until recently, so that a detailed account of the process by Langley and Hadley[43] is the more welcome. Full details are given of the application of the technique, which has the great advantages over spinning of providing variations in thickness and considerable strength from work-hardening.

To find in a technical journal an article devoted to honeycomb sandwiches may seem strange at first sight, but further investigation shows that Cremer[44] is not concerned with the product of *apis mellifica*, but with stiff and very light structures made from thin sheet bonded to an expanded core of honeycomb pattern. Aluminium is used for both sheet and core, and methods of assembly and joining are described.

A large manufacturer of impact extrusions has recently opened a new factory for the production of collapsible tubes, incorporating flow-line methods to eliminate as far as possible the human element. The journey of the tube from slug to decorated and, where necessary, internally coated tube has been recounted.[45] The electric spark machining process has developed considerably over recent years, and Wilms and Wade[46] have presented an account of experience with it on several metals, including aluminium. Some interesting photographs are given of the finish produced and of X-ray diffraction patterns revealing the amount of distortion of the surface, which seems to be at its highest with aluminium.

Joining

Many papers and articles continue to appear on various aspects of the joining of aluminium and its alloys, either to themselves or to other materials. Houldcroft[47] has looked at the present trends in welding aluminium alloys, with special attention to ship construction, in which the argon-arc and self-adjusting arc methods are so widely used. A full account[48] has now been published of the papers presented and discussions recorded at the Symposium on the Use and Welding of Aluminium in Ships, held in 1955, and is a valuable source of information on many aspects of the subject.

Present developments in gas-shielded arc welding in America have been described by Pilia.[49] He points out that the process has only been in use since about 1948, and yet it is already applied manually, mechanically and automatically to many metals, and is the first choice where precision welding is required. Several example weldments are described and illustrated, including some of aluminium. Lesnewich and Cushman[50] have studied the power supplies used for inert-gas-shielded metal-arc welding, and have concluded that no single one is suitable for all the applications of the process. They show which variants are most efficient for each type of

welding, and state that the best general-purpose power source is the constant voltage transformer-rectifier unit with automatic regulation for line voltage changes. The work of Dowd[51] on inert shielding gases for welding aluminium is rather academic in British eyes, since he concludes that a mixture of helium and argon is the optimum, giving sounder welds, less cracking, lower costs, and wider range of voltage, current, and welding speed. But we have no helium, and must make do with argon.

Kehoe and Bichsel[52] have modified an inert-gas-shielded metal-arc welding equipment so that it may be used for producing a localised arc-weld of controlled time, and they give a formidable list of advantages of this process for plug-welding, or joining by a series of spot-butt or spot-fillet welds, including low cost as compared with resistance welding, portability of equipment, and ease of mechanisation. In an investigation of the rate at which an arc-welding electrode melts, Wilson[53] and his collaborators include some measurements for inert-gas shielded welding of aluminium. They show that the rate of melting is the sum of the rates due to arc melting and to I^2R heating of the length of the electrode extending beyond the contact tip, and is twice as high for copper as for steel and aluminium.

The principal field of aluminium resistance welding continues to be in aircraft construction, and Farrell[54] has described many application in primary structures, in both European and American plants, and in several metals, including, of course, aluminium. Concluding that present techniques of spot-welding are not susceptible to sufficient improvement to provide the degree of weld reliability required for modern high speed aircraft, Peterson and Funk[55] have presented some thoughts on a "monitor" method of examining each weld as made, by computing the various important weld factors electronically. They admit that a reliable monitor is not yet forthcoming, but contend that the search for it should be pursued.

Drawn tube is an expensive wrought form, and other methods of tube production are therefore always of interest. Speeds of up to 120 ft./min. can be attained by the use of a new production method announced in America,[56] a development of the Yoder mill principally devoted to the manufacture of irrigation tube, for which a constant demand is experienced. Jones and Powers[57] have tackled the problem of section thinning that is one of the drawbacks of pressure welding, and by using ultrasonic vibrations have enabled very thin materials to be joined without the application of heat. Aluminium foil may be joined to materials of heavy sections, and sintered aluminium powder products are weldable by this method.

There is often a need to join unlike metals together, and Miller and Mason[58] did not select the easiest problem when they elected to weld stainless steel to aluminium. Perhaps brazing might be a better term, since the method adopted was to coat the stainless steel with aluminium brazing alloy and then effect a joint by laying down a bead of aluminium-silicon filler alloy. The joints were strong, and resisted a salt-spray test, but pitted badly in hot tap-water. A somewhat similar method has been applied by Cook and Stavish[59] to join aluminium and copper bus-bars, the copper being coated first with silver solder, and again aluminium-silicon alloy filler wire was used for welding. These authors call their process braze-welding, and they obtained satisfactory electrical conductivity.

A number of interesting accounts have appeared of practical applications in industry of the welding of aluminium. Thus, Roberts and Cardinal[60] have described the fabrication procedure adopted in making an aluminium deck edge elevator for an aircraft carrier, involving many welded joints between tubes, and demanding very careful design and joint preparation. Also in the marine field, Du Cane[61, 62] has given accounts of the design and assembly of a high speed launch in aluminium alloy. Weltman[63] gives details of machine settings and welding sequences in the manufacture of tipper lorry bodies in aluminium alloy, that vary from 12 to 22 ft. in length. Tungtsen-arc welding has enabled an American Company[64] to raise its output of refrigerator cooler units in aluminium to 300,000 per year.

A particularly significant example of automatic argon-arc welding[65] is in the production of milk-churns in aluminium-magnesium-silicon alloy, the whole churn being fully heat-treated after welding to give high strength with no weakening due to heat-affected zones.

The roll-bonding of aluminium is another idea coming originally from America, and Keller[66] has described the technique applied there to the manufacture of heat exchangers. He refers to a similar process in use in Germany where sheets are joined, not by hot-rolling, but by hot pressure-welding in a press which only acts on the areas to be welded. As his contribution under the same title Burgess[66] has discussed British experience, and suggested that the term "roll-welding" is preferable to "roll-bonding." A fair comment might be that that which we call a rose, etc., but one must always have in mind the views of the Red Queen. Moreover, an anonymous contributor[67] to another journal obviously feels the term roll-welding to be correct, as he incorporates it in his title. The article is a general description of the manufacture of a refrigerator evaporator unit by this method. A somewhat different product has been given the name "tube-in-strip," and it has been described and its possible uses enumerated. No details are given of its manufacture.[68]

In his general article on the powder cutting of metals, Casey[69] is rather pessimistic about the application of the method to aluminium, since the cut edges produced are rough and coated with hard oxide. Roper[70] is much more sanguine about the use of the inert-gas-shielded metal-arc process, using a mild steel wire ; he feels that for heavy sections of strong aluminium alloys the process shows distinct promise.,

The mechanism of removal of oxide from aluminium by welding and brazing fluxes has been the subject of a number of explanations, but now Jordan and Milner[71] have put forward an electro-chemical theory which states that the oxide is undermined by the action of a cell set up between the oxide and the metal. The solution potential of aluminium in fluxes is found to fall as the fluoride content increases, and this is interpreted as accounting for the greater efficiency of fluxes containing fluorides.

Solders for aluminium have long attracted the attention of inventors, but the last few years have seen a concentration of serious work on this seemingly very difficult problem. Jewell[72] has described the Thesscal hard solders recently developed, and the fluxes used with them ; he makes corrosion tests involving immersion in boiling water and in salt water, and also salt spray tests, which show that the joints have a high resistance to corrosion. This author devotes some attention to

recently developed soft solders for aluminium, the two principal methods for their use being with a non-corrosive flux or by removing the oxide film under a pool of solder by brushing with a glass or refractory fibre brush. A recently introduced flux[73] for the soldering of aluminium conductor cables has eliminated the necessity to step back the ends of conductor wires, and splay out the inner wires before soldering, a very considerable advance. The method of application of the flux and solder has been described.

Many of the advantages of soldering, without the attendant risks of reducing resistance to corrosion, may be obtained by using metal adhesives. Johnson[74] has reviewed the properties of the adhesives available, and evaluated the resistance of glued joints to elevated temperatures, ageing and fatigue loading. In a later paper, the same author[75] discribes the equipment used in metal bonding, from huge autoclaves for the curing of joints in aircraft structures to simple means based on screw clamps. Edwards[76] has investigated the effect of surface treatment before bonding on adhesive joint strengths in various metals. The best result with aluminium was obtained by degreasing and treatment in a sulphuric acid/sodium dichromate solution, which gave a surface having a contact angle with water of 0°.

Constitution

No great volume of constitutional work has been reported in 1956, but a few interesting papers have appeared. Jaffe and Bever[77] have investigated the solidification at various rates of cooling of aluminium-zinc alloys containing 2–70% zinc. They conclude that undercooling increases with the rate of solidification, and that all samples contained non-equilibrium eutectic in addition to cored primary solid solution. Zinc concentrations on a microscale were deduced from micro-hardness readings and by autoradiography, fair agreement resulting from the two methods. Using micrographic technique, Nowak[78] has determined the solid solubility limits of lithium in aluminium up to 1·6% lithium. He puts forward reasons for the lack of agreement amongst the results of previous investigations.

Following his work on the response to age hardening of aluminium-copper-lithium alloys, Hardy[79], with Silcock, has studied the phase relationships in these alloys. At 500° C., three ternary intermetallic compounds are shown to come into equilibrium with the aluminium-rich solid solution, and their compositions have been determined. The same compounds are present at 350° C., and phase sections have been drawn for both these temperatures. Further work has been reported on the solid solubilities of tin, indium and cadmium in aluminium. Samuels[80] postulates that the values found by Hardy for the solubilities of tin and indium, using a metallographic method and electrolytically polished specimens, are in error because segregated areas were mistaken for undissolved particles. He puts forward his own values obtained by an improved method of mechanical polishing.

New electron-microscope observations of the sequence of the precipitation process in an aluminium-4% copper alloy have been described by Langer.[81] He states that the precipitation of the θ^1 phase occurs in slip planes and polygon boundaries, but not in grain boundaries, and suggests that this is due to those sites representing areas of numerous regularly arranged dislocations in a lattice having a relatively high degree of order.

Willey[82] has described a novel filtering method for separating liquid from solid in the study of alloy systems. The filtering medium is porous carbon and the apparatus is so arranged that after holding the alloy for a period sufficient to ensure a close approach to liquid/solid equilibrium, pressure forces the liquid through the carbon, leaving the solid phase behind.

Properties

The mechanism of creep in metals continues to fascinate investigators, and many of them work with aluminium. Guard and Hibbard[83] have determined the tensile creep properties of high purity aluminium, using constant stress loading, and examined the data found in the light of present-day theories. They consider that the reason for the failure of these theories to account for the results obtained may lie in structural variations, including marked changes in grain size. Continuing his creep investigations, McLean,[84] with Farmer, has made tests on several metals, including aluminium alloy RR58, each at one temperature, and on super-purity aluminium at several temperatures between 100° and 500° C. The results confirm that for all the metals tested the ratio of elongation to grain boundary sliding remains constant throughout any one creep test, but is not always related to the size of the sub-crystals formed. Brunner and Grant[85] have also studied grain boundary sliding, calculating its contribution to total tensile elongation, and have derived, by means of the higher mathematics, equations by which they are able to calculate the elongation of a tensile specimen caused by sliding along any particular grain boundary. Again, Grant[86], this time with Chang, has shown that in high purity aluminium grain boundary sliding is always accompanied by fold formation in the grain on which the new boundary surface is created, and that there is bulk movement of two grains along a mutual boundary, although it is likely that one grain is oriented more suitably for slip to occur in it.

Lambot[87] has bent and heat-treated single crystals of super-purity aluminium, and studied them by a high-resolution X-ray method. A clearly resolvable sub-structure was observed; below 500° C. recovery was accomplished by polygonisation, while above that temperature grain growth was the main phenomenon. Using aluminium of 99·6% purity, Graham and Cahn[88] have measured the rate of growth of a grain growing into a strained single crystal by the method of heating, cooling, and etching to reveal successive boundary positions. They show that results by this method do not agree with those obtained by X-rays, and conclude that this is due to abnormal recovery in the strained grain caused by the heating and cooling. In a separate paper, the same authors[89] have decribed their investigation of the oriented growth theory of recrystallisation textures, using the same materials noted above. They found growth rates to be insensitive to orientation, and that new grains growing preferentially into a strained crystal have random orientation, except that orientations near that of the matrix or its twins are avoided.

Underwood and Marsh[90] have subjected single crystals of aluminium-copper and aluminium-magnesium alloys to constant stress creep tests, and to tensile tests, and measured their hardness at various temperatures. A number of conclusions are presented, but again perhaps the most significant one is that no satisfactory confir-

mation was obtained of any of the theoretical and empirical descriptions of the creep process.

Using microscopic observations during creep tests, Chang and Grant[91] have studied the intercrystalline fracture of a number of materials, concentrating particularly on coarse grained aluminium-20% zinc alloy. They show that intercrystalline cracking may be initiated in one of three ways: when accommodation by deformation in the grain and transmission from one grain to another ceases; when boundary sliding gives at a triple point three-dimensional stresses that exceed the cohesive strength of the grain boundary; or when the inability of a grain boundary to transmit strain gives cracking due to bending stresses. The illustrations of cracking included in this paper are most impressive. Working with aluminium as well as other metals, Machlin[92] has investigated the possibility that creep-rupture may occur by condensation of vacancies. He concludes that the nucleation of voids by vacancy condensation is highly improbable, but that the growth of existing voids by this mechanism is probable.

Lequear and Lubahn[93] have observed that while in a tensile test on aluminium-magnesium-silicon alloy sudden change in constant strain rate causes an abrupt change from one stress-strain curve to another, parallel one, a similar effect is not produced under creep conditions. By a specially devised test they show that the nature of the previous steady state conditions disturbed by the sudden change is one of the factors affecting the transient behaviour.

The effects of magnesium, silver and copper on the slip of pure aluminium have been studied by Thomas and Nutting,[94] who show that while magnesium and copper hinder the formation of lamellae within slip bands, silver encourages it, but lowers the lamellae displacement. They conclude that those elements that greatly distort the solvent lattice prevent the formation of slip lamellae and render difficult duplex slip, so that alloys with such elements work harden more readily.

Zone-melted aluminium of very high purity is known to recrystallise at room temperature, and claims have been made of samples recrystallising at temperatures as low as −50° C. Demmler[95] found no evidence of recrystallisation taking place at the temperature of dry ice, but at room temperature the onset of recrystallisation depended on the degree of cold work, being complete after 90% cold rolling in 1¼ hours, while specimens rolled 10% showed signs of the start of recrystallisation after a few months. A lecture on precipitation phenomenon by so distinguished an authority as Guinier[96] is an important event, and has been reported in full. The general conclusions drawn are that exact knowledge is scanty, while some facts have been established, upon which both theoretical and practical workers may build.

Broom, Molineux and Whittaker[97] have carried out fatigue tests on high strength aluminium-magnesium-zinc-copper alloys and aluminium-7% magnesium alloy at room temperature and in liquid air. They conclude that the relatively low fatigue/tensile strength ratio for D.T.D. 683 alloy is due to overaging during fatigue loading, and point out that this means that the development of aluminium alloys of high fatigue strength is very difficult, as the strong alloys depend upon precipitation phenomena for their strength. Sebisty and Edwards[98] have compared the distribution of fatigue cracks in clad and unclad aluminium-copper-magnesium heat-treated alloy sheet, and shown that the behaviour is appreciably different, cracks being initiated at a much later stage in the test in the case of the bare material. The effects of thickness were also noted.

Continuing his work on the aluminium-copper alloys containing cadmium and other elements, Hardy[99] has studied the effect of cadmium on the response to ageing of aluminium-copper, aluminium-copper-lithium, and aluminium-lithium alloys. He shows that the ability of cadmium to promote preferential nucleation in aluminium-copper-lithium alloys is specific to certain precipitates, and that, in general, the search for trace elements to promote precipitation should be concentrated on alloys in which the nucleation of the precipitate is rather difficult. With Liddiard, Hardy[100] has published a general account of the aluminium-copper-cadmium alloys, with details of semi-fabrication, heat-treatment, corrosion resistance and directional properties. The authors feel that there is considerable scope for these alloys where moderately high strength is required combined with ease of fabrication.

Champion and Spillett[101] have given a full, illustrated description of the production, properties and applications of super-purity aluminium and the commercial alloys based upon it. They stress particularly the attractive finishes that may be obtained on these materials, which show so much promise in applications such as motor-car trim. It has long been known that if the magnesium content of alloy LM4-M in B.S.1490 is near the limit specified, difficulty is experienced in obtaining the required elongation on test-bars, and the trouble is accentuated by high copper. Gittins and Mew[102] have studied a wide series of compositions in alloys of this type, and conclude that even if the copper content were to be as low as 1%, a range of composition could be found to give the properties of LM4; with both silicon and copper present, the top limit for magnesium would be approximately 0·3%.

In the Boiler and Pressure Vessel Code of the American Society of Mechanical Engineers, stress tables are given for aluminium and its alloys, at normal and elevated temperatures, a considerable advance on the position in this country where no such data are available. Holt[103] has reviewed the characteristics of the materials covered, together with design problems and fabrication processes, and he illustrates some typical applications.

What Europe knows as S.A.P. (sintered aluminium powder) America calls A.P.M. (aluminium powder metallurgy) but, as Juliet said, and has already been mentioned above, what's in a name? A survey of the properties of this material has been provided by Lyle,[104] stressing particularly its high temperature strength, and mentioning that it may be electroplated or hard anodised.

Corrosion and Protection

Tout, say the French succintly, *passe*, and this is as true of metals as of anything else in this dark world and wide. Most metals, according to Champion,[105] form some alloys which are liable to failure by stress corrosion under certain conditions, and he shows that while aluminium is no exception, very few of its alloys are susceptible to this type of attack; indeed, only three commercial alloys are cited. Champion considers a cladding of adequately anodic metal to be the best protection for susceptible alloys. Working with aluminium-7% magnesium alloy, Farmery and Evans[106] have assessed the effects of several factors on the stress

corrosion cracking of sheet in salt solution. They note, for instance, that junction of the stressed sample with copper greatly shortens the life, as might be expected. The absence of conspicuous corrosion products and bright fracture show that the total chemical action is not large ; this is in agreement with practical experience of stress corrosion failure in certain aircraft components.

Commercial purity aluminium is known to be a suitable metal for contact with pure water below 100° C., but with liquid water above that temperature uniform corrosion is experienced. Draley and Ruther[107] have studied this phenomenon, and shown that reduction in pH reduces the attack, and increase in pH accelerates it. Paradoxically, connection to some cathodic materials had no undesirable result at 200° C., while at 315° C. the effect was beneficial. Corrosion is prevented by adding to the water cations which are reduced on the metal to low hydrogen overvoltage metals, or by alloying the aluminium with the same metals. Thus an aluminium-1% nickel alloy seems to be completely safe against penetrating attack up to 350° C.

Best and McGrew[108] have investigated the effect of brines on metals, including aluminium and some of its alloys, and the efficiency of inhibitors. They found that commercially pure aluminium and aluminium-magnesium alloy were virtually unattacked by uninhibited sodium chloride brines, while corrosion of high strength aluminium-zinc-magnesium-copper alloy was completely stifled by the addition of 0·5% chromate. Work on the effect on aluminium of calcium chloride solution was not completed. Using hydrofluoric acid solution and barium hydroxide solution as corrodants, Straumanis and Wang[109] have show that there is no difference in corrosion rate between cold rolled and annealed metal, so far as super-purity aluminium is concerned ; cold hammered metal corroded more rapidly. With an alloy containing 1 to 2% copper, however, differential heat-treatments produced differing rates of attack. Mercury is death to aluminium, either as metal or in the form of its salts ; Plumb, Brown and Lewis[110] have used a radioactive tracer method to record mercury pick-up and its distribution on aluminium alloy specimens. As an incidental piece of information, they describe how to remove mercury from aluminium ; a solution of 70% nitric acid and 5% chromic acid proved the most efficient.

As part of a programme of testing aluminium radiators, Twiss and Guttenplan[111] have spun discs of aluminium brazing sheet at high velocities in various natural waters and anti-freeze solutions. They conclude that the type of corrosion occuring at high velocities is the same as at low velocities, and may be inhibited by several agents : of these only soluble oils were considered suitable for use with anti-freeze solutions. The inhibition is somewhat less when the brazing sheet is in contact with brass.

As mentioned above, one of the chief drawbacks of soft soldered joints in aluminium is their susceptibility to corrosion. Smellie[112] has compared soldered joints using tin, lead, cadmium, zinc and alloys based on these metals as solders, by immersion tests in cold 3% salt solution and in boiling tap water. Electrochemical interface failure resulted with tin, lead and cadmium, but zinc-base solders underwent slow attack on the solder itself, and are to be preferred for a wide range of service conditions.

The principal causes of corrosion of aluminium alloys used in ship construction are the choice of the wrong material and contact with other metals resulting in galvanic attack, and Kingcome[113] has quoted a number of examples of both in ships of the Royal Navy. He suggests that the adaptation of cathodic protection to aluminium alloys will in the future enable even the high-strength aluminium-copper-magnesium alloys to be used for ship construction, which certainly seems doubtful at present.

Linicus and Krekel[114] have summarised recent developments in the surface treatment of aluminium, including mechanical methods, preparation for painting, anodising both for corrosion resistance and for abrasion resistance, brightening, and vitreous enamelling. They also mention rubberised coatings produced by spraying with latex solution or by vulcanising straight on to the metal. The increasing use of aluminium for the cladding of buildings has concentrated interest on durable finishes for outdoor service, and Bailey and Evans[115] have discussed the treatments available, with some reference also to finishes suitable for vehicle trim. To obtain finishes comparable with chromium plate, it is necessary to use super-purity aluminium and alloys based upon it. Brace[116] has reviewed the industrial methods for chemical brightening of such materials, and the anodising techniques to go with them. He also gives tests for properties of the finishes, including film thickness, brightness, abrasion resistance and durability. In a general consideration of the brightening of metals, Silman[117] refers briefly to both electrolytic and chemical brightening of aluminium. Much has been heard of the Erftwerk process of chemical brightening, developed in Germany and the subject of patents, but it has only recently been operated on a production scale in this country. It was announced in the middle of the year that a well known company had taken out a licence[118], and was prepared to accept material for treatment.

Whatever the method of brightening, the application of a protective anodised film must follow. Berg[119] has told his readers what they should know about anodised coatings, devoting a good deal of attention to the hard variety used to confer abrasion resistance. He also mentions the effect on properties, such as the reduction in fatigue resistance, caused by thick coatings. An important part of the cost of anodising small parts lies in the racking, and Flusin[120] has put forward a number of solutions to the problem. For instance, he proposes baskets of various shapes for batch anodising small articles, assembly in juxtaposed cylinders for round cans, contact being made by a loop of wire, and stacking in towers for rectangular solids.

It is nowadays fully realised that with all metals paint adhesion and life depend in large measure on the correct pretreatment of the metal suface before painting. In a general review of the pretreatment processes available, Lewis[121] draws attention to those that are suitable for aluminium. The body of the famous Land Rover utility vehicle is an assembly of formed panels of aluminium-2¼% magnesium alloy, and the treatment of these components before painting has been described.[122] Trichlorethylene degreasing is followed by spraying with Alocrom 1200 solution, washing and drying, and details of the plant are given.

While noting the excellent corrosion resistance of aluminium, Fabian[123] stresses the disadvantages in loss of appearance that result from long outdoor exposure, and claims that a special cellulose acetate butyrate

lacquer of low viscosity lends very efficient protection to the metal. This lacquer is named Half-Second Butyrate ; the drying time to permit safe handling is 15 minutes.

The use of aluminium to protect iron and steel against corrosion and scaling is increasing, and a number of papers have appeared dealing with the subject. In a general account[124] of recent developments in metal spraying, mention is made of the virtues of dual zinc/aluminium sprayed coatings to get the best of both worlds. Most authorities spray separate layers of each, but a truly composite coating may be obtained by the powder process using pre-mixed powders. Lawrance[125] gives a number of examples of aluminium sprayed steelwork, including the new Black Bridge at Hook, near Basingstoke; Crown Street Bridge, Carlisle; and chimneys at the Fawley refinery, near Southampton. The internal surfaces of the pipe lines in the Glen Affric hydroelectric scheme were sprayed with 0·003 in. of aluminium following 0·003 in. of zinc, the sprayed metal being painted with bitumen paint. The wire process is a popular method of metal spraying, and Plaster[126] has discussed its history and present applications. He refers to the aluminium-sprayed steelwork at Margam, noting that welding points were left free of spray and the welds treated subsequently. More recent work has shown that aluminium-sprayed steel may be both powder-cut and welded successfully.

During discussion of papers on sprayed coatings presented in 1955, a contributor suggested that it was unlikely that sprayed aluminium coatings provided cathodic protection as each sprayed particle was surrounded by insulating oxide. This led to an interesting technical correspondence,[127] and the suggestion that research on the subject is required. The debate, no doubt, continues.

The " burning " of valves is a phenomenon by no means strange to motorists. Thurber refers to it as " frying " ; his mother was convinced that it is caused by driving an automobile with no petrol in the tank. Rose[128] has described a method of alleviating the trouble by spraying the valve faces with aluminium and heat-treating to give diffusion. In accelerated performance tests, no aluminised valves failed in 50,000 miles, while uncoated valves began to fail at 25,000 miles.

Hughes[129] has again described the manufacture, properties and uses of hot-dip aluminised steel, and he shows that while the process is accepted in America and the Scandinavian countries, it is only at the beginning of its commercial application here.

Applications

One of the earliest fields of application of aluminium was the building industry, and examples from the last century are still in service. The principal uses in building have been reviewed,[130] including glazing bars, windows, rainwater goods and roof coverings, and the importance of the development of aluminium curtain walling has been stressed. Various methods of curtain walling, and of partitioning in aluminium, have also been described in an account[131] claiming to set forth a rational approach to the use of aluminium in building. The last sentence of the article points out that rising demand and lower metal prices are interdependent. A recent interesting example of aluminium wall cladding is the new Marchwood Power Station,[132] incorporating aluminium structural sections and glazing bars, and corrugated sheets of special profiles. At a cost less than the price obtained for the scrap lead removed, a church in Oxfordshire has been re-roofed with aluminium-manganese alloy sheet, fully supported by the existing timber boarding.[133] Another form of roofing for which aluminium is increasingly used is for reservoirs, and two self supporting domes have been built for the Biggleswade Water Board,[134] the structure being in alloy HE10-WP and the sheeting in NS4-$\frac{3}{4}$H.

On the structural side, Marsh[135] has described a foot bridge spanning a steep-sided valley in Switzerland, made from sections formed from sheet in alloy NS4-$\frac{1}{2}$H, joining being by riveting, using rivets in alloy HR30-WP. In order to speed up the building of the Hardwar Centenary Bridge[136] north of Delhi in India, a 130 ft. launching truss in aluminium alloy was used to move the precast concrete beams, weighing up to 50 tons, into position.

Muckle[137] has considered the stage reached in the development of aluminium alloys in shipbuilding, and pointed out that the next major step is the extension of their use to the main structural strength members of the ship. He feels that the establishment of welded aluminium in ship construction may well be more rapid than was the case with welded steel. The largest welded aluminium super-structure[138] yet made is on the motor ship " Bergensfjord " which sailed on May 14, 1956, from the Tyne. 320 tons of plate and 100 tons of sections were used, in aluminium-4$\frac{1}{2}$% magnesium alloy. Three aluminium alloy launches[139] made by the now well-known " Two-Way Tension " system have been delivered from Bideford, North Devon, all sheet being in alloy NS5.

The world's most powerful single-unit diesel-electric locomotive,[140] the English Electric " Deltic ", has a roof made from sections and sheet in aluminium-5% magnesium alloy, construction being by inert-gas shielded metal-arc welding. The same alloy is used for the engine's fuel tanks and train heating boiler water tanks. Twenty-eight all-welded aluminium hopper wagons[141] have recently been added to the rolling stock of a Canadian railway, for service in the transport of bauxite. Again consumable-electrode welding was used, structural members being in alloy HE20 and plate in NP5/6. America's first overhead monorail transit system[142] began operating in Houston, Texas, early in 1956 ; only one car was then in use, and aluminium alloy was incorporated in its framework.

Much experience has been gained over the years in the design and construction of aluminium alloy road transport vehicles, and a recent description of a modern body building works[143] illustrates how this knowledge is applied. All extruded sections are in alloy HE10-WP, and sheet mainly NS4 with some S1C, while castings in LM6 and forgings in HF10 are also used. Panel beating is done by means of a Fokker power-operated hammer. The reflectivity to radiant heat of aluminium is particularly advantageous in refrigerated vehicles, and an account has been given[144] of the design and manufacture of a large capacity refrigerated box van, panelled with stucco sheet, and of an insulated container for mounting on a separate chassis. Aluminium is much used in internal combustion engines, as pistons, cylinder blocks, cylinder heads, etc., and Alcock[145] has reviewed these applications. Crankcase covers for diesel engines may be made economically in aluminium alloy by pressure die casting[146] ; no machining is required other than the drilling of the attachment holes.

The high electrical conductivity of aluminium, together with its low price compared with competitive materials, account for its increasing use in the electrical industry. Ridpath[147] has assessed the contribution of the metal in that industry, and shown how technical problems are being solved as a result of the economic urge. An interesting electrical application of aluminium alloy is the Pontop Pike[148] aerial erected for the B.B.C.; it carries television and v.h.f. radio. The radio aerial takes the form of a cylindrical aluminium cladding round the mast itself, composed of slotted quadrants made from framing in alloy HE10-WP, and sheet in SIC-$\frac{3}{4}$H, with castings in LM6-M at the top and bottom of each quadrant. One of the problems of power station operation is the sticking of fine coal to corroded mild steel plate, and this has been avoided recently by using hoppers and chutes[149] made from aluminium alloy by consumable electrode welding. Conveyor buckets for coal and coke,[150] in alloy NP5/6, are proving much superior to those in steel for gaswork use, as they resist so well corrosion by the wet fuel.

Although less aluminium is used on the farm in this country than in America, the durability of the metal is a great attraction in an industry not noted for its attention to maintenance. A large installation of cylindrical grain silos[151] in corrugated aluminium sheet has recently been made at a mill at Adderbury in Oxfordshire. Each silo has a capacity of about 100 tons of grain. Bailey[152] has described correct procedures for the cleaning of aluminium dairy equipment, and shown that trouble due to attack by alkalis may be avoided by selection of a detergent from the many inhibited varieties that are available.

Nearly 10% of the semi-fabricated aluminium produced in this country is consumed in packaging,[153] and the various uses of sheet and foil in this field have been reviewed. Angel[154] has presented an account of the manufacture and applications of aluminium foil and foil laminates. He mentions the new technique of food preservation by radiation sterilisation, and points out that aluminium is the best of the common metals for transmitting such radiation.

Two articles[155, 156] in the same journal issue have emphasised non-aircraft uses of aluminium alloy forgings and stampings, including motor vehicle fittings, scaffold clamps, cycle parts, railway buffers and so on. One author refers in his title to the "growing reality" of such forgings. What could be more real than a forging? It is neither such stuff as dreams are made on, nor is its little life rounded with a sleep. Some esoteric meaning obviously lies concealed here.

Handforth[157] has summarised the properties of the aluminium-magnesium alloys, both wrought and cast, and their application in industry. He concludes with the pregnant remark that, if the need should arise, it would be possible, with comparatively slight modifications, to produce alloys of this type and "with mechanical properties not less than those of the super durals." There is one aluminium alloy designation that means all things to all men, although they may not be sure of individual nuances, and Mills[158] has reviewed the applications of the materials that it covers.

Although aluminium is used in America for broadly the same purposes as in this country, the proportions of the tonnage of the metal produced that go to various user industries are not the same, so that it is very valuable to have Frary's[159] brief summary of applications in the United States.

Standards

Although the revisions of the British Standards for aluminium and its alloys in cast and wrought form, namely B.S.1490 and B.S.1470–1477, are dated 1955, they were published very late in that year, and comment upon them has appeared in 1956. Elliott[160, 161] has discussed the standards, drawing attention to the differences between them and their predecessors, and the reasons for the changes. He also described the new materials that have been added and their special properties, and explains the considerable importance attached to standardisation by the aluminium industry.

An interesting series of articles[162] has appeared throughout 1956 summarising the requirements of foreign standards for wrought light alloys; the standards of America, Canada, France, Germany and Switzerland have received attention, and the series continues. The information is principally tabular, and the author has refrained from serious comment on the standards; it would be most useful if, at the end of the series, some thoughts could be presented on points of similarity and difference and their metallurgical origin. Possibly by that time international recommendations by the International Standards Organisation might be available to serve as a yardstick.

The increasing use of insulated cables with aluminium conductors has necessitated the standardisation of these conductors, and B.S.2791[163] was published during the year. Also in the electrical field B.S.2706[164] covers aluminium conduit, with cast aluminium alloy and zinc alloy fittings. Much butter, margarine and other food is now wrapped in aluminium foil/vegetable parchment laminates, and these have been standarised in B.S.2758.[165]

The Ministry of Supply continues to issue its D.T.D. specifications, and D.T.D. 741[166] covers ingots and castings in an aluminium-4% copper-2% magnesium-0·7% cobalt alloy used fully heat-treated to give average proof stresses on test bars of 16 tons/sq. in. The aluminium-5% zinc-0·6% magnesium casting alloy mentioned earlier in this article is the subject of D.T.D. 5008,[167] which states that naturally-aged chill-cast test samples have an average proof stress of 12 tons/sq. in., with an elongation on 2 in. of not less than 5%.

A number of British Standards have appeared specifying aluminium alloy components for aircraft use, including hexagon nuts[168] and bolts,[169] mushroom head bolts[170] and pan head bolts,[171] all with unified threads. The new tendency to use 100° countersunk rivet heads in aircraft construction following American practice has been signalised by the issue of a British Standard[172] for rivets with this type of head.

REFERENCES

The Aluminium Development Association maintains extensive Library facilities, and is prepared to lend its accessions for short periods to bona-fide enquirers in this country.

1 Thurber, J. "Recollections of the Gas Buggy," 36–40, "The Thurber Carnival," Hamish Hamilton, pp. 369.
2 Thomas, W. J. "Aluminium in the Economy of the United Kingdom," *Light Metals*, 1956, **19**, 345–347.
3 Anon. "The Aluminium Smelter—Bell Bay Tasmania," *ibid.*, 317–319.
4 Anon. "French Aluminium Industry," *Metal Industry*, 1956, **88**, 205–208.
5 Anon. "French Aluminium Developments in Africa," *Light Metals*, 1956, **19**, 26–27.
6 "The Volta River Project," H.M.S.O., 1956.
Vol. I. Report of the Preparatory Commission.
Vol. II. Appendices to the Report of the Preparatory Commission.
Vol. III. Engineering Report to the Preparatory Commission.
7 Anon. "Ingot Design for Production Efficiency," *Light Metals*, 1956, 19, 52–53.
8 Anon. "Metalworks Palletisation," *Metal Industry*, 1956, **89**, 437–438.
9 Sawers, A. S. H. "Jobbing Production of Light-Alloy Castings," *Foundry Trade Journal*, 1956, **100**, 195–206.

10 Anon. "Automation in Gravity Die-Casting," *Light Metals*, 1956, **19**, 182.

11 Millward, H. J., and Patridge, G. B. "Melting and Handling Light Alloys." *ibid.*, 247–251.

12 Dew, S. B. "Foundry Control and Metallography as Aid to Heat Treatment," *ibid.*, 242–245.

13 Olson, G. B., "Stabilisation of Aluminum Alloy Castings," *Metal Progress*, 1956, **69**, (4), 79–80.

14 Logan, A. "A New Combined Degassing-Modification Process," *Light Metals*, 1956, **19**, 122–125.

15 Thury, W., and Kessler, H. "An Effective Method of Grain Refining for Hypereutectic Aluminium-Silicon Alloys," *ibid.*, 225–227.

16 Kessler, H., and Winterstein, H. "Significance of Particle Size of a Grain Refining Agent," *ibid.*, 294–296.

17 Whitaker, Marjorie. "The Influence of Mould Variables and Inhibitors on Mould Reaction in Aluminium—10% Magnesium Alloy," *J. Inst. Metals*, 1956, **84**, 351–356.

18 Jay, R., and Cibula, A. "Influence of Magnesium Content on Layer Porosity and Tensile Properties of Sand-cast Aluminium-Magnesium Alloys B.S. 1490 LM10 and B.S. (Aircraft) L53," *Foundry Trade Journal*, 1956, **101**, 131–142.

19 Ransley, C. E., and Talbot, D. E. J. "The Routine Determination of the Hydrogen Content of Aluminium and Aluminium Alloys by the Hot-Extraction Method," *J. Inst. Metals*, 1956, **84**, 445–452.

20 Rochow, W. F., and Brashares, C. A. "Refractories for Aluminum and Copper Production," *Journal of Metals*, 1956, **8**, 1070–1073.

21 Smith, F. H. "Aluminium Casting Alloys," *Light Metals*, 1956, **19**, 149–151.

22 Anon. "Alloy 40-E for High Strength Castings," *ibid.*, 238.

23 Sendzimir, M. G. "The Sendzimir Cold Strip Mill," *Journal of Metals*, 1956, **8**, 1154–1158.

24 Durst, G. "A New Development in Metal Cladding," *ibid.*, 328–333.

25 Feltham, P. "Extrusion of Metals," *Metal Treatment*, 1956, **23**, 440–444.

26 Anon. "Extrusion of Light-Alloy Sections," *Sheet Metal Industries*, 1956, **33**, 53–57.

27 Anon. "British Aluminium Extrusion Plant," *Welding and Met. Feb.*, 1956, **24**, 20–21.

28 Anon. "Tube Drawing," *Metal Industry*, 1956, **89**, 106.

29 Wilson, C. "Large Forgings," *Aircraft Production*, 1956, **18**, 374–382.

30 Anon. "Giant Forging Presses," *Metal Industry*, 1956, **89**, 369–372.

31 Vernon, C. S. J. "Progress in Ultrasonic Examination," *Welding and Met. Fab.*, 1956, **24**, 93–97.

32 Anon. "Lubrication Problems in the Hot Working of Aluminium," *Light Metals*, 1956, **19**, 281–282.

33 Anon. "Recent Heat Treatment Furnace Installations," *Metallurgia*, 1956, **53**, 257–275.

34 Griffin, E. "Cold Roll-Forming and Manipulation of Light-Gauge Sections," *J. Inst. Metals*, 1956, **84**, 181–197.

35 Edwards, R. D. "Stretch-Forming of Non-Ferrous Metals," *ibid*, 199–209.

36 Perry, T. G. "Bending and Allied Forming Operations," *ibid.*, 211–216.

37 Fielding, J. "Rubber Pressing," *ibid.*, 147–159.

38 Johnson, W. "Research into some Metal-Forming and Shaping Operations," *ibid.*, 165–179.

39 Grainger, J. A. "The Deep Drawing and Spinning of Sheet Metal, with Particular Reference to Non-Ferrous Materials," *ibid.*, 133–146.

40 Galloway, D. F. "The Machining Properties of Non-Ferrous Metals," *ibid.*, 121–131.

41 Barlow, D. A. "The Cold Forming of Aluminium Alloys," *Welding and Met. Fab.*, 1956, **24**, 286–289.

42 Bucey, B. K. "Metalworking Advances," *Metal Industry*, 1956, **88**, 168–170.

43 Longley, R. G., and Hadley, W. "Metal Flow-Turning," *Sheet Metal Industries*, 1956, **33**, 519–529.

44 Cremer, G. D. "Production of Honeycomb Sandwich Structures" *Metal Progress*, 1956, **70**, (5), 81–84.

45 Anon. "Continuous Production System for Collapsible Tubes," *Light Metals*, 1956, **19**, 112–113.

46 Wilms, G. R., and Wade, J. B. "Some Observations with the Electric Spark Machining Process," *Metallurgia*, 1956, **54**, 263–268.

47 Houldcroft, P. T. "Trends in the Welding of Aluminium Alloys," *ibid.*, **53**, 80–83.

48 Symposium, "The Use and Welding of Aluminium in Shipbuilding," The Institute of Welding, 1956, pp. 144.

49 Pilia, F. J. "Recent Developments in Inert-Arc Welding," *Welding Journal*, 1956, **35**, 40–46.

50 Lesnewich, A., and Cushman, E. "Power Supplies for Gas-Shielded Metal-Arc Welding," *ibid.*, 655–664.

51 Dowd, J. D. "Inert Shielding Gases for Welding Aluminum," *ibid.*, 207S–210S.

52 Kehoe, J. W., and Bichsel, H. J. "Inert Gas-Shielded Metal-Arc Spot-Process," *ibid.*, 895–903.

53 Wilson, J. L., Claussen, G. E., and Jackson, C. E. "The Effect of I^2R Heating on Electrode Melting Rate," *ibid.*, 1S–8S.

54 Farrell, W. J. "Resistance Welding in the Aircraft Industry," *Welding and Met. Fab.*, 1956, **24**, 167–174, 217–223.

55 Peterson, J. M., and Funk, E. R. "A Systems Analysis Approach to Aircraft Spot-Weld Reliability," *Welding Journal*, 1956, **35**, 679–683.

56 Anon. "High-Speed Induction Welding of Aluminium Tubing," *Sheet Metal Industries*, 1956 **33**, 192.

57 Jones, J. B., and Power, J. J. "Ultrasonic Welding," *Welding Journal*, 1956, **35**, 761–766.

58 Miller, M. A., and Mason, E. W. "Properties of Arc-Welded Joints Between Aluminum and Stainless Steel," *ibid.*, 323S–328S.

59 Cook, L. A., and Stavish, M. F. "Welding Aluminum to Copper Using Inert-Gas Metal-Arc Process," *ibid.*, 348–355.

60 Roberts, S. I., and Cardinal, O. P. "Large-Scale Aluminum Fabrications," *ibid.*, 1125–1127.

61 Du Cane, R. C. "An All-Welded Aluminium High-Speed Motor Launch," *British Welding Journal*, 1956, **3**, 1–9.

62 Du Cane, R. C. "Aluminium Fabrication in Boat Building," *Welding and Met. Fab.*, 1956, **24**, 235–240.

63 Weltman, C. W. "Welding an Aluminum Dump Body," *Welding Journal*, 1956, **35**, 49–50.

64 Anon. "Tungsten-Arc Welding Helps Raise Refrigerator Production to 300,000 Units," *ibid.*, 476.

65 Anon. "Aluminium Milk Churn Production," *Welding and Met. Fab.*, 1956, **24**, 242–243.

66 Keller, H., and Burgess, N. T. "Roll Bonding of Aluminium," *Sheet Metal Industries*, 1956, **33**, 801–805, 810.

67 Anon. "Roll-Welded Heat Transfer Sheet," *Light Metals*, 1956, **19**, 35[illegible]–357.

68 Anon. "Tube Forming by Inflation," *Metal Industry*, 1956, **88**, 253–254

69 Ca[illegible]y, E. T. "Powder Cutting," *ibid.*, 23–27.

70 Roper, E. H. "Thermal Cutting of Aluminum, Stainless Steels and High-Nickel Alloys," *Welding Journal*, 1956, **35**, 915–920.

71 Jordan, M. F., and Milner, D. R. "The Removal of Oxide from Aluminium by Brazing Fluxes," *J. Inst. Metals*, 1956, **85**, 35–40.

72 Jewell, R. C. "Hard Soldering of Aluminium and Aluminium Alloys," *Sheet Metal Industries*, 1956, **33**, 606–614.

73 Anon. "Aluminium Conductor Cable Joining," *Metallurgia*, 1956, **54**, 274–275.

74 Johnson, R. A. "Metal Adhesives," *Welding and Met. Fab.*, 1956, **24**, 134–136.

75 Johnson, R. H. "Equipment for Metal Bonding," *ibid.*, 447–451.

76 Edwards J. A. "The Effect of Surface Treatment on the Properties of Adhesive-Bond Joints in Metals," *Sheet Metal Industries*, 1956, **33**, 311–314, 322.

77 Jaffe, D., and Bever, J. B. "Solidification of Aluminum-Zinc Alloys," *Journal of Metals*, 1956, **8**, 972–975.

78 Nowak, S. K. "Solid Solubility of Lithium in Aluminum," *ibid.*, 553–556.

79 Hardy, H. K., and Silcock, J. M. "The Phase Sections at 500° C. and 350° C. of Aluminium-Rich Aluminium-Copper-Lithium Alloys," *J. Inst. Metals*, 1956, **84**, 423–428.

80 Samuels, L. E. "The Solid Solubilities of Tin, Indium, and Cadmium in Aluminium," *ibid.*, 333–336.

81 Langer, E. "Electron-Microscopic Observations on the Precipitation of the Theta' Phase in an Aluminium—4% Copper alloy," *ibid.*, 471–472.

82 Willey, L. A. "Filtering Apparatus for Study of Liquid-Solid Equilibria in Alloy Systems," *Journal of Metals*, 1956, **8**, 263–264.

83 Guard, R. W., and H bbard, W. R. "Tensile Creep of High Purity Aluminum," *ibid.*, 195–199.

84 McLean, D., and Farmer, M. H. "The Relation During Creep Between Grain-Boundary Sliding, Sub-Crystal Size, and Extension," *J. Inst. Metals*, 1956, **85**, 41–50.

85 Brunner, H., and Grant, N. J. "Calculation of the Contribution made by Grain-Boundary Sliding to Total Tensile Elongation," *ibid.*, 77–80.

86 Chang, H. C., and Grant, N. J. "Mechanism of Grain-Boundary Sliding," *Journal of Metals*, 1956, **8**, 169–170.

87 Lambot, H. J. "Sub-Structure Formation in Slightly Bent Aluminium Single Crystals," *J. Inst. Metals*, 1956, **84**, 473–474.

88 Graham, C. D., and Cahn, R. W. "Measurement of Grain Growth Rates in Recrystallisation," *Journal of Metals*, 1956, **8**, 504–508.

89 Graham, C. D., and Cahn, R. W. "Grain Growth Rates and Orientation Relationships in the Recrystallisation of Aluminum Single Crystals," *ibid.*, 517–521.

90 Underwood, E. E., and Marsh, L. L. "Effect of Alloying Elements on Plastic Deformation in Aluminum Single Crystals," *ibid.*, 477–483.

91 Chang, H. C., and Grant, M. J. "Mechanism of Intercrystalline Fracture," *ibid.*, 544–551.

92 Machlin, E .S. "Creep-Rupture by Vacancy Condensation," *ibid*, 497–501.

93 Lequear, H. A., and Lubahn, J. D. "Some Transient Effects During Creep and Tensile Tests of an Aluminum Alloy," *ibid*, 497–501.

94 Thomas, G., and Nutting, J. "The Plastic Deformation of Aluminium and Aluminium Alloys," *J. Inst. Metals*, 1956, **85**, 1–7.

95 Demmler, A. W. "Recrystallisation of Zone-Melted Aluminum," *Journal of Metals*, 1956, **8**, 958–959.

96 Guinier, A. "Precipitation Phenomena in Supersaturated Solid Solutions," *ibid.*, 673–682.

97 Broom, T., Molineux, J. H., and Whittaker, V. N. "Structural Changes During the Fatigue of some Aluminium Alloys," *J. Inst. Metals*, 1956, **84**, 357–363.

98 Sebisty, J. J., and Edwards, J. O. "Some Metallographic Observations on the Fatigue Failure of Bare and Clad Aluminium-Copper-Magnesium Alloy Sheet," *ibid*, 291–297.

99 Hardy, H. K. "Trace Element Effects in Some Precipitation-Hardening Aluminium Alloys," *ibid.*, 429–439.

100 Liddiard, E. A. G., and Hardy, H. K. "Aluminium-Copper-Cadmium Alloys," *Metal Treatment*, 1956, **23**, 67–71.

101 Champion, F. A., and Spillett, E. E. "Super-purity Aluminium and its Alloys," *Sheet Metal Industries*, 1956, **33**, 25–36.

102 Gittins, M. G., and Mew, W. E. "The Effect of Composition on the Mechanical Properties of Al-Si-Cu-Mg Casting Alloys," *Metallurgia*, 1956, **54**, 71–76.

103 Holt, M. "Aluminum and Aluminum Alloys for Pressure Vessels," *Welding Journal*, 1956, **35**, 308S–312S.

104 Lyle, J. P. "Aluminum Powder Metallurgy Products," *Materials and Methods*, 1956, **43**, (4), 106–111.

105 Champion, F. A. "The Interaction of Static Stress and Corrosion with Aluminium Alloys," *Metallurgia*, 1956, **53**, 63–68.

106 Farmery, H. K., and Evans, U. R. "The Stress Corrosion of Certain Aluminium Alloys," *J. Inst. Metals*, 1956, **84**, 413–422.

107 Draley, J. E., and Ruther, W. E. "Aqueous Corrosion of Aluminum," *Corrosion*, 1956, **12**, 441t–448t, 480t–490t.

108 Best, G. E., and McGrew, J. W. "Inhibiting Corrosion of Steel, Aluminum and Magnesium Intermittently Exposed to Brines," *ibid.*, 285t–292t.

109 Straumanis, M. E., and Wang, Y. N. "The Effect of Cold Work and Heat Treatment on the Rate of Dissolution of Pure and Impure Aluminum in Acids and Bases," *ibid.*, 177t–182t.

110 Plumb, R. C., Brown, M. H., and Lewis, J. E. "A Radio Chemical Tracer Investigation of the Role of Mercury in the Corrosion of Aluminum," *ibid.*, 277t–285t.

111 Twiss, S. B., and Guttenplan, J. D. "Corrosion Testing of Aluminum," *ibid.*, 263t–270t, 311t–316t.

112 Smellie, W. J. "Soldered Joints in Aluminium: Mechanism of Corrosion," *Light Metals*, 1956, **19**, 210–214.

113 Kingcome, J. C. "Corrosion Problems Arising from the Use of Aluminium Alloys in H.M. Ships," *Corrosion Prevention and Control*, 1956, **3**, (6), 31–34, **3**, (12), 37–40.

114 Linicus, W., and Krekel, P. "Surface Treatment of Aluminium," *Metal Industry*, 1956, **88**, 185–187.

115 Bailey, J. C., and Evans, W. "Aluminium Finishes for Exterior Use," *Metallurgia*, 1956, **53**, 57–62.

116 Brace, A. W. "Industrial Methods for the Chemical Brightening of Aluminium," *Metal Finishing*, 1956, **2**, 317–324.

117 Silman, H. "Metal Brightening," *Metal Industry*, 1956, **88**, 105–108.

118 Anon. "Erftwerk Finishing Process for Aluminium," *Light Metals*, 1956, **19**, 262.

119 Berg, R. V. V. "Anodised Coatings for Aluminum," *Materials and Methods*, 1956, **44**, (1), 90–94.

120 Flusin, M. "Batch Anodising," *Metal Industry*, 1956, **89**, 413–416.

121 Lewis, M. "The Pretreatment of Metal Surfaces," *Sheet Metal Industries*, 1956, **33**, 639–646.

122 Anon. "The Treatment of Aluminium Body Panels prior to Painting, at the Works of the Rover Co., Ltd.," *Metal Finishing*, 1956, **2**, 47–50, 60.

123 Fabian, R. J. "New Protective Lacquer for Aluminum," *Materials and Methods*, 1956, **44**, (3), 104–105.
124 Anon. "Recent Developments in Metal Spraying," *Corrosion Prevention and Control*, 1956, **3**, 38–42.
125 Lawrance, G. R. "Flame Spraying of Metals and Plastics," *Corrosion Technology*, 1956, **3**, 254–257.
126 Plaster, H. J. "Metal Spraying by the Wire Process," *British Welding Journal*, 1956, **3**, 73–77.
127 Letters to the Editor of *Chemistry and Industry*, 1956.
Evans, U. R., 195–196.
Higgins, W. F., 382–383.
Tolley, G., 464.
Walkiden, G. W., 528.
128 Rose, K. "New Aluminised Coating," *Materials and Methods*, 1956, **43**, (3), 105.
129 Hughes, M. L. "Hot-dip Aluminised Steel, its Preparation, Properties and Uses," *Sheet Metal Industries*, 1956, **33**, 87–97.
130 Anon. "Aluminium in the Building Industry," *Light Metals*, 1956, **19**, 152–154.
131 Anon "Building and Aluminium—A Rational Approach," *ibid.*, 284–285.
132 Anon. "Extensive Use of Aluminium Cladding at the New Marchwood Power Station," *Metallurgia*, 1956, **53**, 198–199.
133 Anon. "Fully Supported Aluminium Church Roof," *ibid.*, **54**, 84.
134 Anon. "Aluminium Reservoir Roofs," *ibid.*, 289–290.
135 Marsh, C. "Footbridge in Formed Aluminium Sheet," *Light Metals*, 1956, **19**, 91–93.
136 Anon. "Novel Lightweight Launching Truss," *ibid.*, 342.
137 Muckle, W. "Aluminium in Shipbuilding," *ibid.*, 105–106.
138 Anon. "The Motor Ship Bergensfjord," *ibid.*, 193.
139 Anon. "Three New Light Alloy Lauches," *ibid.*, 87.
140 Anon. "Building English Electric Locomotives," *Welding and Met. Fab.*, 1956, **24**, 344–351.
141 Anon. "All-Welded Aluminium Hopper Wagons," *Light Metals*, 1956 **19**, 46.
142 Goodell, M. "Welding in Houston's Monorail," *Welding and Met. Fab.* 1956, **24**, 412–413.
143 Anon. "Modern Works for Light Alloy Bodybuilding," *Light Metals*, 1956, **19**, 84–86.
144 Anon. "Refrigerated Vehicle and Insulated Container," *ibid.*, 307–309.
145 Alcock, J. F. "Light Alloys in Internal Combustion Engines," *ibid.*, 51.
146 Anon. "Die-Castings for Industrial Diesel Engines," *Metal Industry*, 1956, **88**, 89–91.
147 Ridpath, C. H. E. "Contribution of Aluminium to the Electrical Industries," *Light Metals*, 1956, **19**, 156–159.
148 Anon. "Pontop Pike Aerial," *ibid.*, 140–141.
149 Anon. "Aluminium Hoppers and Chutes for C.E.A.," *ibid.*, 203–204.
150 Anon. "Light Alloy Conveyor Buckets for Coal and Coke," *ibid.*, 180.
151 Anon. "Corrugated Aluminium Grain Silos," *Sheet Metal Industries*, 1956, **33**, 321–322.
152 Bailey, J. C. "Cleaning and Sterilising Aluminium Dairy Equipment," *Dairy Engineering*, 1956, **73**, 40–42.
153 Anon. "Aluminium—The Material for Packaging," *Light Metals*, 1956, **19**, 146–148.
154 Angel, T. H. "Aluminium Foil and Foil Laminates," *J. Inst. Packaging*, 1956, **3**, (29), 305–310.
155 Willis, A. W. "The Importance and Growing Reality of Aluminium—Alloy Forgings in Industry," *Light Metals*, 1956, **19**, 174–176.
156 Anon. "Aluminium Forgings in Every day Use," *ibid.*, 172.
157 Handforth, J. R. "Aluminium-Magnesium Alloys and their Industrial Application," *ibid.*, 108–110.
158 Mills, F. J. "The Role of Duralumin and Other Wrought Aluminium Alloys in British Industry," *ibid.*, 101–103.
159 Frary, F. C. "The Light Metals in American Economy," *Metal Progress*, 1956, **70**, (3), 179–132.
160 Elliott, E. "The 1955 Specification Revisions," *Light Metals*, 1955, **18**, 409–412, 1956, **19**, 56–59, 80–82.
161 Elliott, E. "British Standards for Aluminium and its Alloys," *Metallurgia*, 1956, **53**, 108–112, 157–162.
162 Anon. "International Standards for Wrought Light Alloys," *Light Metals*, 1955, **18**, 375–379, 1956, **19**, 22–23, 185–186, 279–280, 322–323.
163 B.S. 2791 : 1956 "Aluminium Conductors in Insulated Cables."
164 B.S. 2706 : 1956 "Non-Ferrous Conduit and Conduit Fittings (Aluminium and Zinc Alloy)."
165 B.S. 2758 : 1956 "Vegetable-Parchment/Aluminium-Foil Laminates (Parchfoil) for Wrapping Diary and Other Food Products."
166 D.T.D. 741 : January, 1956. "Aluminium-Copper-Magnesium-Cobalt-Niobium Alloy Ingots and Castings."
167 D.T.D. 5008 : March, 1956. "Aluminium-Zinc-Magnesium Alloy Ingots and Castings."
168 B.S. 2A107 : 1956, "Aluminium Alloy Nuts (Unified Hexagons and Unified Threads) (Ordinary and Slotted) for Aircraft."
169 B.S. 2A169 : 1956 "Aluminium Alloy Bolts (Unified Hexagons and Unified Threads) for Aircraft."
170 B.S. 2A170 : 1956 "Aluminium Alloy (B.S.L65) Mushroom Head Bolts (Unified Threads) for Aircraft."
171 B.S. 2A171 : 1956 "Aluminium Alloy Pan Head Bolts (Unified Threads) for Aircraft."
172 B.S. S.P.68 to 71 : 1956 "100° Countersunk Precision Head Aluminium and Aluminium Alloy Rivets for Aircraft."

Structural Aluminium Research Scholarship

THE Institution of Structural Engineers accepted, in 1954, an offer by the Aluminium Development Association of a Research Scholarship to enable the holder to undertake research on some aspect of the application of aluminium alloys to structures. It is expected that a report of the research work carried out under the first award of the Scholarship made in 1954 will be published towards the end of the present year.

The conditions of this Scholarship have recently been revised and it is now open for award every third year for a two-year period, the value of the Scholarship being £600 per year. It is the intention of the Institution to make the next award of this Scholarship in 1957 with a view to the successful applicant commencing his investigations at the beginning of the University Session in October next. Entries for the Scholarship to be awarded this year close or March 31st, 1957. The Scholarship is administered by the Institution and further particulars, together with forms of entry, should be obtained from the Secretary of the Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1.

Plating Shop Layout Competition

THE Midland Branch of the Institute of Metal Finishing is organising a competition for the Institute to encourage younger members to take an interest in productivity in the industry. The subject of the competition is plating shop layout and, very briefly, candidates will be supplied with an outline of the plating shop and a list of process tanks and plant which they will have to incorporate in the design. They will have to lay out the shop so that it would be capable of handling the normal variety of work encountered in a jobbing shop with the maximum efficiency possible.

Full details of the competition will shortly be published by the I.M.F., and entry forms may be obtained from the offices of the Institute, 32 Gt. Ormond Street, London, W.C.1. Three main prizes will be awarded : First £30, Second £20, and Third £10. Entry is restricted to members of the Institute who were aged not more than 35 on December 31, 1956.

Slab Casting Machine Exports

A PAPER to be presented at the Annual Meeting of the A.I.M.E. in New Orleans, on February 24th, on "An Induction Melting Furnace for Zinc Cathodes and a Casting Machine for High Purity Zinc Slabs," will deal with a slab casting machine supplied by Sheppard & Sons, Ltd., of Bridgend, Glamorgan. Three of these machines have been installed by The Consolidated Mining and Smelting Co., Ltd., of Canada, and a little over a month ago a fourth was ordered. More recently The American Smelting and Refining Co., Ltd., placed an order with the Bridgend firm for a third machine for their plant at Corpus Christi, U.S.A. Collectively, the total value of Sheppard's exports to the American Continent exceeds 200,000 dollars.

Lead Stock Disposals

THE Board of Trade, after seeking trade advice about the best way to dispose of lead from the Board's stocks without unduly disturbing the market, have decided to sell about 30,000 tons of lead for delivery and pricing over a period of nine months beginning in March. Some 4,000 tons of this will be offered by open competitive tender and the remainder, to which special considerations apply, will be offered back to the original suppliers or their agents. The availability of tender forms for the 4,000 tons will be advertised in due course.

High Strength Aluminium Casting Alloy 40-E: D.T.D. 5008

Latest Developments and Foundry Experience

By J. F. Gardner* and M. R. Hinchcliffe†

Alloy 40-E was introduced to this country a few years ago as a high strength aluminium casting alloy, having as alloying elements zinc, magnesium, chromium and titanium, and since that time increasing use has been made of it. Following an outline of the properties of the alloy, consideration is given to its melting and casting characteristics, and the article concludes with a reference to some typical applications.

SINCE the high strength aluminium casting alloy 40-E‡ first became available in the United Kingdom an increasing number of applications of this alloy has been established, and thereby a fairly complete appreciation of its physical properties and foundry characteristics has been obtained. D.T.D. 5008 was recently issued to cover the use of this material for aircraft components, and castings are now being made to the most exacting requirements of the aircraft industry.

Properties of the Alloy

It will be recalled that the alloy has a combination of most desirable physical and mechanical properties, which are obtainable without resorting to heat treatment. High strength with relatively high proof stress, good shock resistance, excellent machinability, and good corrosion resistance and weldability are its main features. Three weeks age hardening at room temperature is sufficient to develop the optimum properties, and the material remains metallurgically and dimensionally stable thereafter. It does not suffer from embrittlement through prolonged ageing.

A number of examples of the use of 40-E will be discussed in detail and a selection of other applications is illustrated.

Before dealing with the foundry characteristics of the alloy, it is relevant to re-state the properties which have attracted attention. Probably the most attractive feature of the alloy is its relatively high strength coupled with toughness. Fig. 1 shows the degree of deflection withstood by a sand cast frame. Although conventional test results support these characteristics in the relatively high proof stress and good tensile and elongation figures, examples such as this, coupled with practical tests of strength on actual castings, demonstrate more forcefully the possible applications for the material. The alloy's hardness, machinability and good colour are other attractive features. Many applications depend primarily on 40-E's good corrosion and stress corrosion resistance, and others on strength with weldability. Practical tests as to corrosion resistance have revealed that the alloy is as good as pure aluminium when used in contact with hydrogen peroxide, and it is equal to aluminium-magnesium alloys in resistance to atmospheric and marine atmospheres. The material anodises well to a good colour, and is particularly amenable to the hard anodising process.

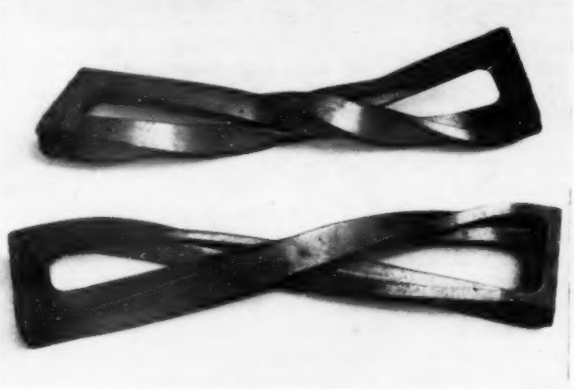


Fig. 1.—Deflection of sand casting under the action of twisting forces.

It is a combination of these various practically attractive properties, incorporated in sound castings, which is establishing the alloy. Cases have arisen where 40-E has replaced wrought aluminium alloys, showing a price advantage by reduced machining costs, and in many other cases 40-E has replaced heat treated casting alloys in castings where heat treatment has proved very expensive or difficult in practice.

The acceptance of a new material by designers and engineers does depend, above everything else, upon the quality of the castings themselves. The use of a high quality alloy invariably means that a high standard of casting quality is required, as distinct from the purely metallurgical requirements. In this respect it is important to record that in practice the machanical properties of 40-E are relatively easy to reproduce in castings. Many examples have arisen where sections from castings have been tested and found to be well above specification requirements, particularly in respect of proof stress values. This is a most important factor to the designer, as it is well known that with certain aluminium alloys the properties in the casting are often inferior to the specification requirements realised in the test bar.

It will be seen from the composition that the alloy employs zinc, magnesium, chromium and titanium as

* Aluminium Division, Associated Lead Manufacturers, Ltd.
† Director, Universal Casting Developments, Ltd.
‡ See Appendix for details of composition and mechanical and physical properties. Alloy 40-E is covered by British Patent 627,968, the sole rights for which are held by Daralum Castings, Ltd., Darlington, for the United Kingdom, Europe and the Commonwealth (except Canada). There are 5 sub-licensed ingot manufacturers and 14 sub-licensed founders in the United Kingdom.

Fig. 2.—Typical feeding system on complex casting.

alloying constituents, and that the maximum limits imposed on the impurities are very low. The narrow limits imposed on the constituents and impurities presuppose a high standard of metal control and good foundry housekeeping. The best combination of mechanical properties is obtained from metal having zinc and magnesium contents of 5·5% and 0·6%, respectively, and care should be taken when using foundry scrap to ensure that these figures are worked to. This does not mean that specification requirements cannot be met from metal with different zinc and magnesium contents, but merely that better results can be obtained when these suggested levels are used. The effect of lower zinc and magnesium contents is to lower the tensile properties and to increase the elongation: this also occurs when the magnesium is low as compared with the zinc. The opposite effects result when both zinc and magnesium are too high.

The thermal characteristics of the alloy indicate that there is a freezing range of 43° C., from 615° C. to 572° C. This immediately classifies the alloy in the group with extended freezing range, and as one requiring careful consideration of running and feeding techniques.

Melting and Pouring

There is nothing abnormal about the conditions required for the satisfactory melting of 40-E, provided that the following recommendations are observed:

(1) A pyrometer is necessary for checking metal temperature.

(2) Melting should take place as rapidly as possible, preferably with throttling down of the burner when melting occurs.

(3) Flame conditions should be adjusted to yield a slightly oxidising atmosphere.

(4) Ample allowance of covering flux should be used (½–1 lb. per 100 lb. melt) and the metal should be "swilled" in the flux by gentle movements with an iron or graphite stirring rod.

(5) The temperature of the metal in the furnace should never exceed 800° C.

In common with other aluminium alloys, 40-E is susceptible to hydrogen absorption, and gas pick-up is best removed by a slow scavenging with nitrogen the final state being determined by visual observation on the freshly exposed surface of the metal in a test cup. Where proprietary degassing compounds are used, it is recommended that "carbon free" or "non-spotting" qualities should be used. Also the quantity of chlorine-containing degassers used should be kept to an absolute minimum, in order to avoid excessive loss of magnesium. It has been found that during normal melting, fluxing and degassing, up to 0·1% of magnesium may be lost, and additions of magnesium should be made to allow for this when using remelted scrap. Additions of magnesium are best made by attaching the required weight of pre-heated magnesium to a rod and plunging it beneath the melt.

The alloy can be melted satisfactorily in any of the common types of furnace, but care should always be taken to avoid excessive or prolonged heating. On the other hand, the temperature of metal held between melting and pouring should never be allowed to approach the liquidus temperature, as in so doing chromium may segregate and poor quality metal result. Chromium segregation can be identified by examining a fracture of the metal which then shows starry inclusions. Cold metal is indicated by coarse columnar grain.

The most suitable form of test bar for sand castings is the standard E-type bar, the moulds for which should be made from an accurate pattern incorporating all the requirements for running and feeding. For diecastings, the wedge type metal mould should be used. At pouring temperatures used for the more common aluminium alloys, the fluidity of 40-E is low, so that an increase in the average pouring temperature is necessary to realise running properties in line with common experience. A useful range of pouring temperatures for 40-E is from 700 to 780° C., depending on the nature of the casting. In general, and as a rough guide, it could be said that castings should be poured at 40° C. higher in 40-E than they would be in, say, LM-4. With a proper appreciation of the increased pouring temperature demanded by this alloy and the use of reliable temperature measuring equipment, there should be no difficulty in running complex castings of thin sections.

Soundness of Castings

Attention has already been drawn to the significance of the freezing range, whereby the alloy passes through an appreciable pasty stage of low strength during its solidification. The shrinkage of 40-E by comparison with the common alloys is high, and ample feeding is therefore necessary, particularly during the pasty stage,

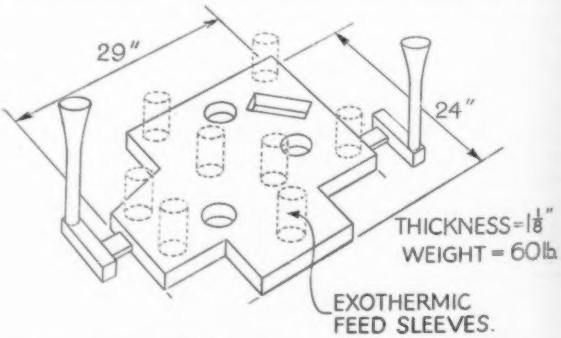


Fig. 3.—Running and feeding system on plate casting in 40-E.

to ensure sound castings. Faults in inadequately fed castings appear as surface draws, tears, cracks or shallow depressions, which are usually associated with a "frosted" skin. A reliable criterion of soundness is the surface appearance, a bright reflective surface is proof of soundness. Castings tend to be hot short and are subject to tearing if restrained by an inflexible mould or core. This characteristic has retarded the use of 40-E in die-castings, but once a full appreciation is obtained of the alloy's behaviour in this respect, hot tearing and cracking can be overcome by using alternative methods of coring, such as sand cores or shell moulded cores. Such tendencies, however, are not wholly controlled by the mould conditions, as the tendency to tear and draw is linked also with the system of feeding, and can be minimised where the latter is adequate and properly integrated.

In the case of pressure diecastings, modifications to existing techniques are usually necessary to allow for the comparatively lower fluidity of 40-E and to compensate for the high shrinkage. This applies particularly to techniques where LM-2 and LM-6 have previously been used. Provided a proper appreciation of these factors exists, pressure diecastings can satisfactorily be made from 40-E.

The shrinkage habits of 40-E mean that the alloy is exacting in its response to foundry technique and casting design. The production of satisfactory castings by any method is therefore largely a problem of understanding these habits as applied to each particular casting form.

Running and Feeding

As regards running and feeding techniques, it has been found that the adoption of top or bottom running depends on the case in question, the former should be aimed at wherever possible because of its encouragement of progressive solidification. Alloy 40-E does not have strong dross-forming tendencies, and top pouring is therefore practicable, providing it is arranged to minimise turbulence. Localised sections must be fed or chilled, but feeding is preferred for one-off items as the results are more predictable. The actual form of feeding heads is very important, as insufficient volume of feed defeats its own end—merely prolonging the solidification of the section and increasing the shrinkage—and a massive

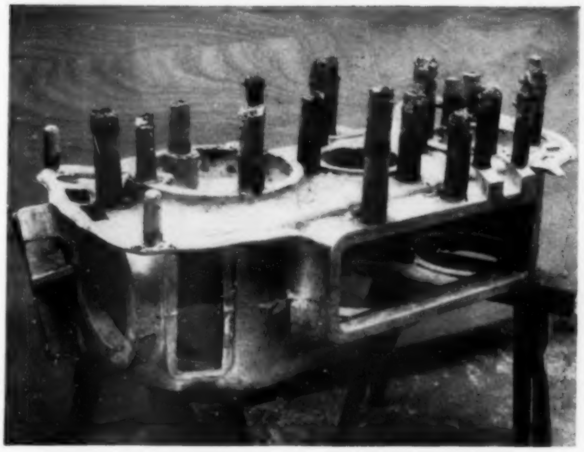
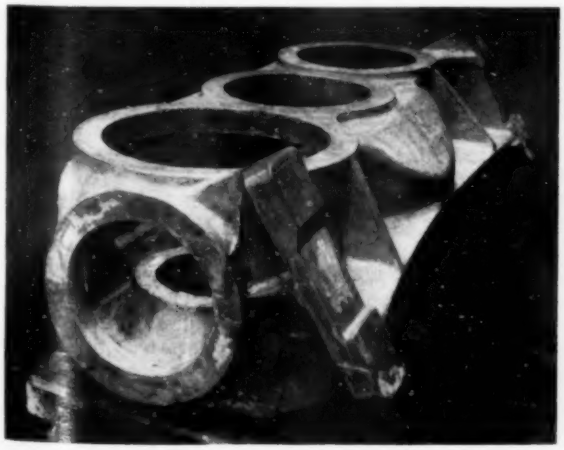


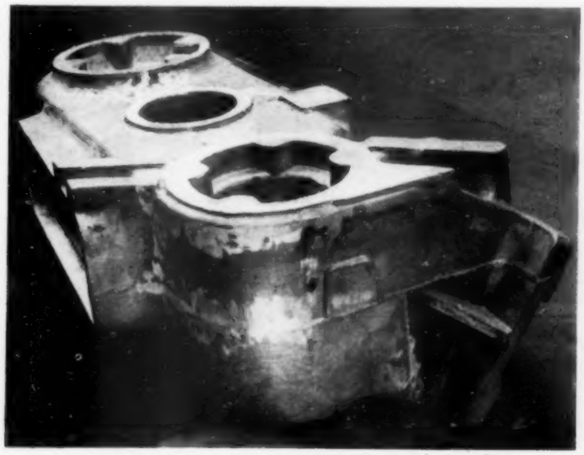
Fig. 4.—Casting in Alloy 40-E showing feeders. Weight 380 lb. when fettled.

feed occupying too great an area retards the cooling of the section with adverse effects. The correct form of feeder for small castings is shown in Fig. 2, and it is essential to have these made in wood for use generally throughout the foundry.

For feeding extensive heavy sections the use of massive feeders is inadvisable and the use of separate, exothermic, feed sleeves is preferred. These give more than an adequate volume of metal, as the whole of the content is available for feed, being liquid much longer than the casting. Also the casting is not defaced and the amount of metal to be returned to the furnaces is much reduced, an important factor with 40-E. For instance, a sleeve of $1\frac{1}{2}$ in. internal diameter leaves a residual head of about 1 lb., and a head of this size is sufficient for most castings, either singly for small bulky castings or multiplied around a large casting.

Fig. 2 shows the gating and feeding arrangement on a small casting incorporating a number of isolated sections. Running is distributed between two flash gates, each $\frac{1}{8}$ in. thick, and the form of the feeders is clear. It so happens that this casting requires to be flawless after machining and polishing on the face cast down, otherwise it would be practicable to make it the reverse way





Figs. 5 and 6.—Casting seen in Fig. 4 (after removal of feeders) showing general features.

Fig. 7.—Hinged pressure closure yoke for 20-in. tank manhole cover for Whessoe, Ltd.

and reduce the amount of feed required. The actual yield on this casting is 60%.

Another casting presenting a feeding problem in 40-E is the plate depicted by the sketch in Fig. 3. The castings were required to be machined all over and to meet exacting standards of inspection. The use of feeder sleeves situated at random presented no difficulty in moulding or dressing, and satisfactory castings were produced with a favourable yield.

Figs. 4, 5 and 6 illustrate an exceptional example of founding in 40-E. This casting weighed 380 lb. when fettled, and was made to meet an order for one-off only. Sectional thickness varies from 1 in. to 3 in., the length being 40 in. Green sand moulding was adopted throughout, including the core, which was necessary to avoid restricting contraction. The casting incorporates webs, pockets and remote heavy sections. A three-part mould was constructed and a distributed running system applied at the top joint. Extensive chilling in the drag mould

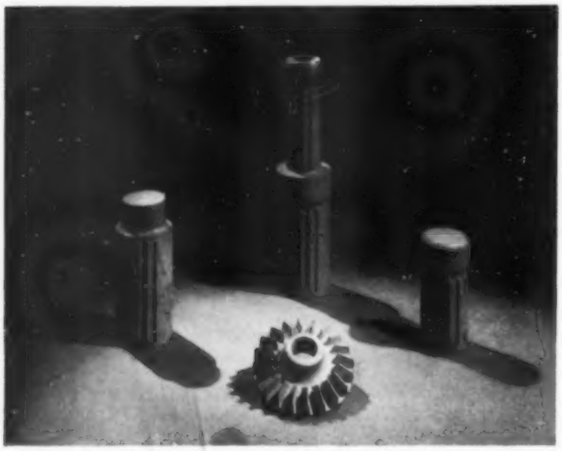


Fig. 8.—Rotor housings and high-frequency fan rotor for Armstrong-Whitworth (Pneumatic Tools), Ltd. The changeover of these rotor housings to 40E castings from machined solid aluminium alloy bar enabled the designer to introduce internal coring, cast-in steel inserts for the pneumatic hose connection, and the raised fluting, to provide a better grip for the tool operator.

and the upper half of the green sand core was applied, in conjunction with exothermic feeders liberally but systematically distributed. The latter were easily removed with a portable cutter, and the very favourable yield ratio of 80% was realised.

Returning to general principles appertaining to shrinkage of 40-E, it is important not to pour at too low a temperature with the idea of reducing shrinkage. This may reduce the actual amount of potential volumetric shrinkage, but it has an adverse effect on the process of feeding. It is probable that if a section, for instance a large area of uniform thickness, tends to solidify before the mould is filled and the full metalostatic pressure realised, then its shrinkage is not compensated, by virtue of the interruption of mass feeding. The symptoms of this condition are isolated patches of drawn and porous metal. It is known that, with alloys of long freezing range, mass feeding or consolidation during the pasty stage is an important feature of the feeding process. In this respect, also, rapid filling is advisable in order to generate the metalostatic head as soon as possible after the initiation of the pour. The same objective is supported by pre-igniting exothermic sleeves to avoid the possibility of an initial " thickening " of the metal in the head at the vital instant.

Fig. 9.—A selection of pressure castings for Normalair, Ltd., to A.I.D. Class I (radiologically examined) standards with dimensional tolerances as low as + 0, – 0·002 in., as cast. All the screw threads are cast to size with no joint mark up the thread.

Moulding Techniques

For sand foundry production, green sand moulds are preferred, and the alloy gives an excellent reproduction from these. It is obvious though that perfect reproduction is also linked up with casting soundness, as any flaw in this appears as a sink and loss of definition, and the resultant shape is not that of the pattern.

A careful control of sand condition, as in normal aluminium foundry practice, is essential to realise the best surface finish and avoid the harmful agitation of the metal which arises if the moisture content is too high.

Mould construction must be such as to avoid excessive restriction of contraction of the metal. For this reason, green sand cores should be used where expedient, other-

wise hard cores with rapid burn-out properties must be applied. Generally speaking, non-collapsible CO_2 cores are not successful, except with small castings.

The alloy responds well to the shell moulding technique, and a high degree of dimensional accuracy can be achieved by this method. Gravity diecastings are now being made from the alloy, although, as mentioned earlier, initial difficulties were encountered which arose from the alloy's shrinkage and feeding characteristics. Pressure diecastings have also been made with success, but here again modifications to established techniques must be made to allow for the characteristic behaviour of 40-E during cooling. Several castings are now in production which require the application of mixed foundry techniques—for example, gravity diecastings with shell moulded cores, and green sand moulds in conjunction with permanent metal mould parts. A very wide range of castings has now been built up in 40-E, and so far no subject has been encountered which cannot be made in this alloy by the application of suitable foundry technique.

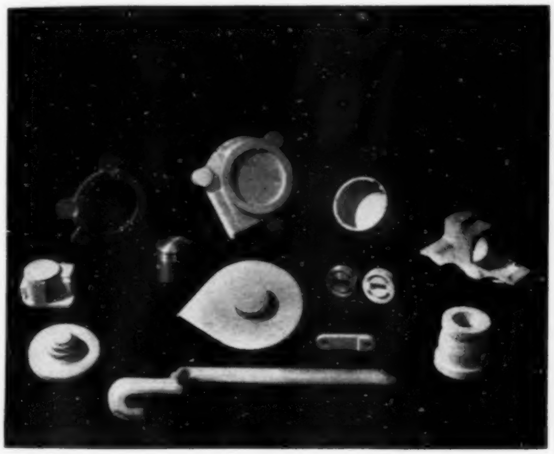


Fig. 10.—A selection of castings for electric motors, car accessories, pistons, and electronic, radar and sound reproduction equipment.

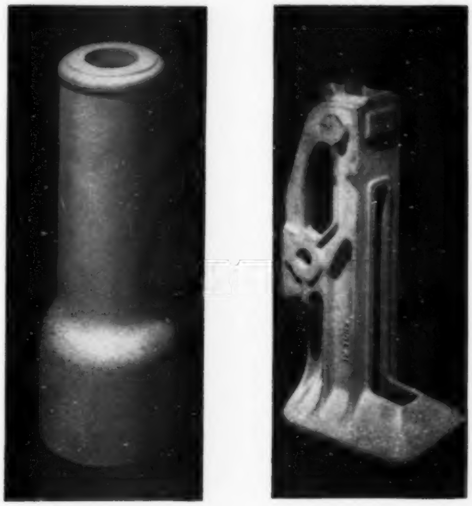


Fig. 11.—Left : Casting for hammer drill barrel subject to heavy shock and vibration in service (Victor Products, Ltd.) ; and right : body casting for a 12-ton lifting jack for Charles Willetts, Junr., Ltd., which replaces a malleable iron casting.

Typical Applications

The following uses of the alloy are of considerable interest. Where good strength is required from large or complicated castings, 40-E is being used in place of heat treated alloys. For example, a large aircraft fuselage component of complicated section was extremely difficult to heat treat, and 40-E was suggested as a solution to this problem. Immediate success was achieved, and it was subsequently found that better average proof stress values were obtained throughout the 40-E castings than had previously been obtained from the same castings made in LM-10. Other examples of this type of application are large frame castings and fork-shaped lever castings. Alloy 40-E has replaced malleable iron in applications where strength and toughness are required, accompanied by reduced weight. Fifteen-ton rail-jack bodies are now being made from the alloy, and its strength and shock resistance properties have led to its use for body castings of rock drills and electric and pneumatic tools. High speed fans and impellors are also made from 40-E for a similar reason. Where corrosion resistance and good finish and strength are required together, 40-E has been successfully used for ships' fittings, aluminium alloy window fittings, oil and chemical plant valves and components, and large foam rubber moulds. Strength with good machinability and pressure tightness have given rise to its use in components of aircraft air pressurisation equipment. Previously, such components were machined from wrought stock, and the castings are now made very largely to finished dimensions by the shell moulding process. Rocket-assisted take-off motor bodies and guided weapon test vehicle parts are now made from 40-E, and pressure diecast internal combustion engine pistons have been successfully made on an experimental scale. A wide variety of general machinery castings, such as gear boxes and housings, show advantages over the same parts made in the more common alloys. Several applications have arisen where machinability and dimensional stability have resulted in the use of 40-E, for example, in scientific and radar apparatus and in sound reproduction machinery. In these cases, accurate machining with fine threads and perfect surface finish is essential.

A range of important motor vehicle castings has been made in France from the alloy's equivalent specification A-Z5G, and an informative paper on the use of this alloy has been published by Chas. Roinet. In the United States, 40-E has been in use for some years in road vehicle axle and differential gear housings, rail-jack castings, oil handling equipment parts, ventilating fans, fire hose fittings and hand tools. In this country the field of applications wherein 40-E can to advantage replace other materials is by no means covered. At this stage, sufficient experience has been gained to show that progressive engineers and founders can employ 40-E wherever its properties suggest advantages over more conventional materials. Typical applications are illustrated in Figs. 7-11.

(*Continued on page* 84).

Correspondence

PARTICLE SIZE DETERMINATION

The Editor, METALLURGIA.

Sir,

In the article by Mr. L. A. Phelps on "Particle Size Determination in Powder Metallurgy" in the October issue, under the heading "Sedimentation and Decantation" there are the following statements :—

"The residue left in the beaker contains all the particles whose settling velocity is greater than s/t. While the decantation portion contains all the particles settling more slowly than s/t."

The second of these statements is incorrect. Those particles with a settling velocity of less than s/t which were in the lower levels of the liquid while it was settling before decantation will settle out with heavier particles from higher levels and will not be decanted. In order to split the particles even into two fractions, above and below a given size, the same suspension must be stirred up and decanted a number of times (as many as thirty times have been recommended) with the same settling time. The settling time is then altered and a similar number of decantations done with the new settling time. Thus the procedure is a good deal more tedious than would appear from Mr. Phelps' article.

Yours faithfully,

G. M. HOLMES,

London and Scandinavian Metallurgical Co., Ltd.
Rotherham.

The Editor, METALLURGIA.

Sir,

With reference to the letter by Mr. G. M. Holmes commenting on my article on "Particle Size Determination in Powder Metallurgy," I must agree with him that those particles with a settling velocity of less than s/t which were in the lower levels of the liquid while it was settling, before decantation, will settle with those particles of settling velocity greater than s/t from the higher levels. It must be noted that the method is only generally suitable for subsieve sizes and in practice those particles above 300 mesh are separated by sieving. It is a common tendency for metal powders to be irregular in shape and the sieving process breaks some of the sharp corners off the particles, thus the percentage of fine particles is increased above that actually in the powder.

Although only an approximation, by ignoring those particles in the lower levels, with a settling velocity of less than s/t that have settled with the heavier particles, this error caused by the breakdown of particles on sieving is cancelled out. As Mr. Holmes pointed out, for a true analysis to be made of a sub-sieve sample provided, one must decant each fraction as much as 30 times. In research problems this is obviously necessary, although one would in these instances use a method such as that employing the rather expensive and elaborate Turbidometer.

For a cheap production-line method of analysing the sub-sieve size of a sample of irregularly shaped metal powder, the relatively quicker and simpler method of sedimentation outlined in my article should prove quite adequate.

Yours faithfully,

L. A. PHELPS.

Pype Hayes, Birmingham, 24.

METALLURGY IN THE NUCLEAR POWER INDUSTRY

OXIDATION OF CAST IRON IN CO/CO_2 MIXTURE

We have received from DR. W. E. DENNIS, author of the article on "Metallurgy in the Nuclear Power Industry," which appeared in our January issue, a letter pointing out that it should not be inferred that the catastrophic oxidation of cast iron shown in Fig. 4 is peculiar to iron made by the Meehanite process. Indeed, experiments being carried out by the author suggest that it will occur with all cast irons containing graphite in the flake form.

High Strength Aluminium Casting Alloy 40-E

(*continued from page* 83)

Acknowledgments

The authors are indebted to their respective companies for permission to publish this article, and to the various firms who have given permission for the publication of photographs of their products.

APPENDIX

Properties of Aluminium Alloy 40-E

SPECIFICATION REQUIREMENTS

Chemical Composition

	%
Magnesium	0·5 –0·7
Zinc	4·8 –5·7
Chromium	0·4 –0·6
Titanium	0·15–0·25
Copper	0·1 max.
Iron	0·5 max.
Manganese	0·1 max.
Silicon	0·25 max.
Lead	0·05 max.
Tin	0·05 max.

Mechanical Properties

	Sand Cast Test Bar	*Chill Cast Test Bar*
0·1% Proof Stress (tons/sq. in.)	10	12
Ultimate Tensile Stress (tons/sq. in.)	14	15
Elongation (%)	4	5

TYPICAL PROPERTIES

Mechanical Properties at Room Temperature

Tensile Strength	16 tons/sq. in.
Yield Strength*	13 tons/sq. in.
Elongation	7%
Brinell Hardness (10 mm., 500 kg.)	75–87
Charpy Impact	2–3 ft. lb.
Shear Strength	12 tons/sq. in.
Endurance Limit (5×10^8 cycles) (Moore type rotating beam machine)	4 tons/sq. in.
Young's Modulus	$10 \cdot 3 \times 10^6$ lb./sq. in.
Modulus of Rigidity	$3 \cdot 8 \times 10^6$ lb./sq. in.

Mechanical Properties at Low and Elevated Temperatures

Treatment	*Yield Strength (tons/sq. in.)*	*Tensile Strength (tons/sq. in.)*	*Elongation on 2 in. (%)*
Low Temperature Strength			
24 hr. at —94° F.	—	17	5
High Temperature Strength			
1,000 hr. at 175° F.	14	15	3
1,000 hr. at 250° F.	12	13	3·5
1,000 hr. at 350° F.	7·5	9	6

* Yield strength determined by extensometer, 0·2% offset.

Crucible Melting Furnaces

Demonstration and Test Foundry at Battersea

General view of the renovated Test Foundry.

THE Morgan Crucible Company has recently reorganised its Test Foundry which has been operating at Battersea Wharf for several years. During this time it has had three main functions : (*a*) to demonstrate the use and advantages of crucible melting, and to show the complete range of Morgan furnaces operating under service conditions ; (*b*) to develop and test crucible furnaces ; and (*c*) to test new types of crucibles and samples from production batches.

Over the years, the Company found that certain aspects of the original layout could be improved, and that the introduction of a number of new features was desirable. Rather than attempt the changes piecemeal, it was decided to close the Test Foundry for a thorough renovation. During this operation, attention has been paid not only to the technical aspects of the work carried out, but also to factors affecting working conditions, such as lighting, ventilation, etc., and the result is a shop of pleasing appearance, adequately ventilated, and equipped with colour-corrected lighting.

The Test Foundry before renovation.

The transformation which has been effected is strikingly demonstrated by a comparison of the " before and after " illustrations. The rough whitewashed brickwork has been given a smooth finish and a pleasing colour scheme has been adopted. The atmosphere has been improved by the installation of remote control motorised roof ventilation and the colour-corrected lighting referred to earlier has been achieved by mounting a tungsten filament lamp alongside a mercury vapour lamp at all lighting points. Mercury vapour lighting has proved itself to be satisfactory for foundry use, but the addition of the tungsten filament lamps enables colours to be observed more accurately. The ingot casting and knock-out area has been floored in steel.

Gone are the fuel tanks, pipework and conduit which festooned the walls prior to renovation. Instead, an oil ring main system has been installed, with a duplicated main heater in the pump-house, and all services are ducted in the floor. To supply air for combustion to all the furnaces a new non-pulsating fan has been provided. Self-contained service panels form part of the ancillary equipment at each furnace and, in addition to fuel supplies, provide connections to the electrical supply and the centralised pyrometer equipment, the instrument of which is located at the end of the shop, beneath the clock. Emergency " thump " switches have been installed for the oil supply.

A Committee of the British Productivity Council is at present making a report on working methods and conditions in non-ferrous foundries, and in making these changes the Company has tried to anticipate the report, by combining in the Test Foundry the best principles of foundry practice and the latest improvements in industrial welfare.

Furnace Installation

As was mentioned earlier, one of the purposes of the Test Foundry is the demonstration of the range of Morgan furnaces operating under service conditions. To this end, examples

Degassing a melt with nitrogen.

of the various types are available, together with ancillary equipment incorporating Morgan products, as detailed below.

The rotary crucible furnace is designed specially for the reclamation of swarf, metal powders, skimmings and dross. The rotating crucible dispenses with pokering and affords considerable reduction in labour costs. It is claimed that higher recovery figures can be obtained under regular production conditions than with earlier methods. Fired by oil or gas, the capacity of the furnace is 672 lb. of brass.

The central axis tilting furnace, Type CA/Mech., is an oil-fired unit of 600 lb. (brass) capacity, but it is at present being fired by gas by means of a simple conversion set of parts. Similar conversions are available for all types of Morgan oil-fired furnaces: they may prove of increasing interest if fuel oil is further restricted. This model of the CA furnace is electrically tilted.

Next in the line of melting furnaces comes the Type HLP Mark II hydraulically operated lip axis tilting furnace, oil-fired and of the same capacity as the Type CA/Mech. unit. This furnace has incorporated a simple aid to fuel economy—SP melting—which can be applied to existing tilting furnaces. The modification is in the crucible itself, which has slots cut in it above the level of the molten metal. These allow the exhaust flame to preheat the top part of the solid charge in the early stages of the melt. Hence the name S.P. (supercharge preheat) melting. The slots are, of course, on the side of the crucible away from the lip so that pouring is not affected. The technique is suitable for most copper and aluminium alloys, especially when remelting ingot and large scrap, provided efficient degassing is used. It is unsuitable for aluminium-magnesium alloys such as D.T.D. 165 and D.T.D. 300, and it may be less suitable with copper alloys containing more than 10% of lead, tin or zinc. It is also unsuitable where metallurgical melt quality is of first importance, particularly when freedom from gas or sulphur is essential. The net result of using SP melting is an increase in crucible life; a saving in time per heat, and hence an increase in productivity; and a reduction in fuel consumption which enables output to be maintained in spite of fuel oil restrictions.

Lift-out furnaces are represented by three units fired, respectively, by oil, gas and coke. Sizes range from 30 lb. to 350 lb. brass capacity, and the chief advantage of this type over the conventional pit type furnace is that it is shallow enough to be worked standing on ground level or in a small pit. The resulting reduction in installation costs will be readily apparent.

The furnace line is completed by two bale-out furnaces. Employing a Salamander plumbago basin, this type of melting unit is ideal for the diecaster. Models are available for melting or maintaining aluminium, copper and zinc alloys in sizes from 100 lb. to 400 lb. and 1,120 lb. (aluminium); and in 200 lb. and 400 lb. sizes for bronze.

At present undergoing extensive tests of crucible and component life in the new shop is an experimental electric resistance bale-out furnace of 300 lb. (aluminium) capacity, which it is hoped will be in production by the middle of the year. It is intended as a maintaining furnace only, and will be run direct from the mains supply. The metal bath temperature is automatically controlled, the immersed thermocouple being protected by a composite silicon-carbide/mullite sheath. It is expected that this furnace will find widespread application in the aluminium die-casting industry.

Among the ancillary equipment in use in the Test Foundry, mention may be made of the Morganite electrographite immersion pyrometer tip tubes and degassing units. A life of between 60 and 100 dips in iron and non-ferrous metals can be expected from the former, which have a high resistance to thermal shocks which enables them to withstand immersion in molten metals without preheating. Two models of the degassing equipment are available, a simple nitrogen cylinder and tube unit for use with the lift-out type of furnace, and the larger unit illustrated here for the tilting furnaces. The immersion tube in each case is made of plumbago. Nitrogen degassing is a purely physical process which has no effect on the composition of the metal, and metal losses are not incurred. A further advantage is that metallurgical control of the operation is unnecessary, as it is impossible to "over degas."

Bronze and Brass Founders Advisory Service

THE Advisory Service organised by The Association of Bronze and Brass Founders under the Conditional Aid Scheme, and inaugurated in 1953 for a period of three years, terminated at the end of September last year. The Association will continue to hold Advisory Meetings, but attendance at these will, in general, be limited to members of the Association. An Advisory Committee is being set up to give all possible help to members with regard to their individual problems; where the resources of the British Non-Ferrous Metals Research Association are required, they will be available to members of the Association's Research Group. Membership of the Association is open to founders in Great Britain producing castings containing not less than 50% copper.

Production Engineering Research

Review of P.E.R.A. Activities in 1956

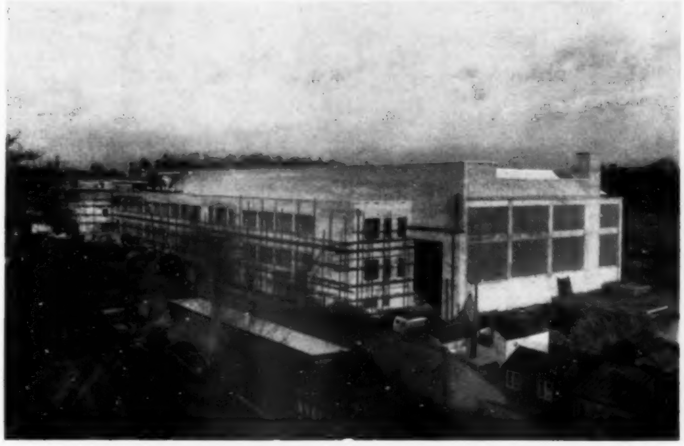


Fig. 1.—A general view of the new research block.

KEENER competition in overseas markets and rising prices at home stimulated greater and more effective use of all PERA research, information and training services by members generally in 1956, in an effort to reduce production costs to a minimum. As the Association's income increased substantially during the year, it was possible both to expand existing services and to introduce new services, such as residential training courses for key personnel in industry, and thus provide members with still further assistance in applying improved production techniques in the particular circumstances existing in each factory.

Considerable progress was made in 1956 with the construction of a new research block costing about £250,000. The building is now nearing completion, as shown in Fig. 1, and will be occupied in a few months.

Research

During the year, general investigations were carried out on machining, stamping, machine tools, impact extrusion, tool grinding, de-burring, cutting fluids, automation, deep drawing, rolling bearings vibration, grinding, machine tool lubrication, surface finish, etc. Nearly 160 practical investigations were also carried out for individual members.

Machining

Drilling—Large increases in drill life and higher rates of production have been reported by a number of firms applying the results of PERA's researches on the drilling of cast iron, steel, and non-ferrous alloys. The wide variation in drill life with point angle when drilling cast iron, titanium alloy, and various steels is shown in Fig. 2. When drilling cast iron, the most suitable point angle varies with the cutting speed and feed, and the type of cast iron drilled, but laboratory and field tests carried out in conjunction with members have led to the development of suitable point shapes for various conditions. Preliminary tests indicate that different methods of thinning drill points which are being investigated by PERA may significantly affect performance. Confirmation of these results is being sought in a further series of tests.

In an investigation of the performance of small drills it was found that there was a marked increase in drill life at a critical feed rate, irrespective of the cutting speed within the range used in the tests. A high-speed drilling machine developed for this investigation is shown in Fig. 3. It consists of a rigid portal frame to eliminate machine deflection effects, a vertically fixed precision drilling spindle, and a hydraulically operated work table. The spindle has been designed for speeds up to 50,000 r.p.m., and is driven by a variable speed D.C. motor; the spindle speed is measured by an electronic tachometer incorporating a photo-electric cell.

Reaming—Research into the effects of reaming conditions on hole accuracy and surface finish showed that increasing the reaming speed, depth of cut, and feed rate above critical values caused a deterioration in hole surface finish and accuracy. Accuracy did not, however, deteriorate quite so rapidly as surface finish, and hence if some increase in surface roughness is acceptable, cutting speeds can be increased without great loss of accuracy. At cutting speeds below the critical values, there was no significant difference in the performance of straight and spiral flute reamers.

Cutting Fluids—Further field tests were carried out with special oil-less cutting fluids developed by PERA.

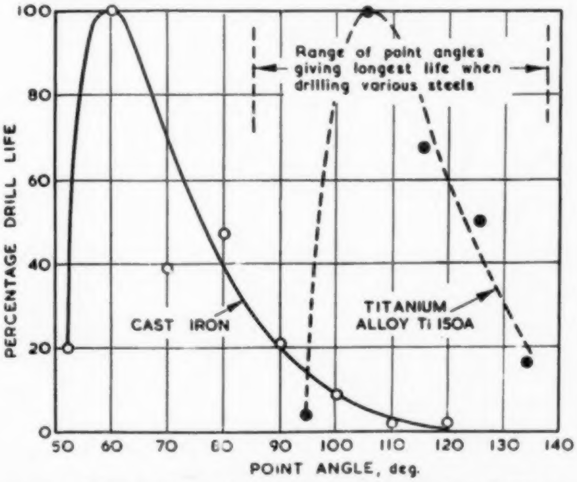


Fig. 2.—Effect of drill point angle on drill life when drilling cast iron, a titanium alloy and various steels.

Fig. 3.—High speed drilling machine developed for an investigation into the performance of small drills.

These fluids are comparable in performance to soluble oils but cost less. The corrosion characteristics of the experimental fluids are comparable to those of soluble oil emulsions. Various methods of applying cutting fluids were also investigated.

Press-Working

Finish Blanking—Research into a "finishing blanking" technique developed at PERA is establishing the most suitable conditions for the production of blanks with smooth crack-free edges without the need for subsequent shaving or machining operations. Significant reductions in production costs have been made by member-firms applying PERA's recommendations for finish blanking a variety of ferrous and non-ferrous materials. For example, in the production of copper components in an electrical firm, a secondary machining operation has been eliminated, and de-burring time has been reduced from 5 to 2 minutes, thus affecting a 60% saving of the original production costs. Finish blanking is also being applied in the production of components in several other industries.

Deep Drawing—Other press-working researches carried out included an investigation to compare the performance of various drawing lubricants. During this work the effect of blank-holder pressure on maximum depth of draw was also studied. Preliminary results indicate that substantial increases in depth of draw can be achieved under conditions which differ markedly from conventional practice.

Work was commenced on an investigation to determine the rates of wear of various tool materials when blanking and piercing mild steel, stainless steel, and electrical lamination steel. The tests are being carried out on a double roll-feed high speed press.

Impact Extrusion—In the last few years, interest has been steadily growing in the cold impact extrusion of steel. Although reports of extensive developments in the extrusion of steel have been published in Germany and the U.S.A., very little progress has so far been reported by the firms in Britain which are engaged on development work. PERA has been investigating the process continuously for the past three years, and in April, 1956, a report on the cold extrusion of carbon steel was issued to all members. Further research is in progress, and it is hoped that large steel components will shortly be extruded on the 1,000 ton press (shown in Fig. 4), which is at present being installed in the new research block. Current research includes investigations into the metallurgical requirements of steels for impact extrusion, and into the most suitable type and thickness of phosphate coating for extruding steel.

Thread Rolling

An investigation into the blank sizes required for rolling unified screw threads showed that blank diameters could be accurately calculated from the geometry of the thread form, provided allowance is made for the effects of various errors which may occur in the rolling dies. The blank sizes given in the report on the investigation should result in the production of Unified Fine and Coarse threads giving class 1A and 2A fits in accordance with B.S. 1580 : 1953.

Machine Tools

Stability devices are being developed to eliminate self-excited chatter when using large overhanging boring bars (see Fig. 5). Substantial progress has also been made in an investigation into various aspects of machine tool slideway lubrication, using the equipment illustrated in Fig. 6.

The first part of an investigation has been completed on the influence of ground and scraped surfaces, lubricant viscosity, load per unit area and sliding speed on the transition from boundary to hydrodynamic lubrication. Practical tests are also being carried out to determine the boundary friction properties of various slideway materials and lubricants for machine tools. Progress on research into vibration and chatter has included the identification of modes of vibration occurring in cylindrical grinding machines and the effect of vibration on

Fig. 4.—This 1,000 ton press will shortly be used for investigations into the extrusion of large steel components.

Fig. 5.—Research in progress on stability devices being developed to eliminate self-excited chatter when using large overhanging boring bars

lobing of cylindrically ground workpieces. Methods have also been developed for determining the natural modes of vibration of centre lathes.

Automation

Work was commenced in 1956 on an operational research into some of the most important aspects of automation in this country and abroad. These include the application of loading and unloading devices and conveyors to machine tools and presses, and the use of magazines, hoppers and vibratory feeders, mechanical hands, and conveyors of all types, including portable units. Particular attention is being paid to automation for batch and small quantity production. Work was completed on the first part of the investigation, and a report was prepared on hoppers and selector devices.

Surface Finish

An investigation into the accuracy of assessing surface finishes by means of plastic replicas showed that substantial errors could arise, and indicated the conditions under which acceptable assessments might be made.

De-burring

An extensive operational research into de-burring methods which has been carried out over a period of three years was completed in 1956 with the preparation of a report on the de-burring of metal pressings. Other reports in this series deal with the prevention of burrs, abrasive blasting, manual and chemical de-burring, barrelling, and the application of a wide range of power-operated de-burring equipment. The reports give details of a large number of improved de-burring techniques for use in the production of all types of component, and also refer to the economic advantages of various methods. Savings arising from the use of the methods described in the reports include a reduction in the time for de-burring gears from 3 minutes to 18 seconds per gear.

Information Services

Technical Enquiries

Very heavy demands were made on the Technical Enquiry Service, which dealt with nearly 2,000 individual requests for technical assistance from members during the year. Many of these problems necessitated close investigation by the Association's engineers on the shop floor, as well as practical investigation in PERA laboratories. These enquiries embrace practically every aspect of manufacture from the delivery of raw materials to the shipment of finished products, including design for production, machining, deep drawing, diecasting, assembly, finishing, inspection, etc. Typical of the economies made by firms applying the Association's recommendations were a saving of approximately £3,000 per annum in the production of bearing shells; a reduction of two-thirds in the cost of producing brush boxes by substituting an impact extrusion for a riveted assembly; a reduction of 100 000 per annum in the number of shells scrapped during deep drawing operations by improving tool design and operating conditions; and a saving of £2,000 on one order for label frames.

Ten thousand enquiries have been dealt with since the service was introduced a few years ago. An increasing number of enquiries can be answered from the files, although most of the requests received are for special assistance in solving problems peculiar to the company concerned. During the year, the Association's engineers also planned or re-organised factories, and made specific recommendations on the production techniques, tooling, types of equipment, layout, production control schemes, etc., to be used in these factories. This has led to increases of up to one-third in the output of existing works.

Visits to Industry

To assist members in obtaining the maximum benefits from the rapidly increasing volume of technical assistance available from PERA in the form of research results, special recommendations, published information, and training courses, approximately 350 visits were made to members by the Association's senior engineers.

Fig. 6.—Various aspects of machine tool slideway lubrication are being investigated on this equipment.

Fig. 7.—The PERA mobile unit comprising cinema or lecture theatre and demonstration van.

Mobile Unit

During the year the mobile unit illustrated in Fig. 7, completed its first tour of members, having visited more than 400 factories and given demonstrations, etc., to about 15,000 industrial personnel. The leading vehicle is equipped as a cinema or lecture theatre, and the trailer can be used as a demonstration bay for talks to workshop personnel. Practical demonstrations of tool grinding and measuring techniques, etc., are also given. A number of films giving practical guidance on impact extrusion, finish blanking, improved grinding techniques, automation, drilling, etc., have been made, and are being shown to factory personnel.

Library

The collection of books, standards, pamphlets, directories, and reports in the Library was increased by 606 items during the year, and the number of technical journals received increased to more than 500 per month. An indication of the growing awareness of British industry generally of the value of technical literature in promoting higher productivity is given by the fact that members requested nearly 70,000 copies of the Monthly Bulletin, which briefly summarizes developments in production techniques, organisation, materials, etc., reported in all parts of the world.

Training Services

The ultimate objective of PERA's researches is the reduction of production costs through the application of research results in member-firms. Various educational activities have therefore been developed to secure prompt and effective application of research results in industry. These activities include one-day refresher courses for foremen and other supervisory staff, open days, etc. The success of these activities led to a demand for longer courses for key production personnel, and it was therefore decided to hold an experimental series of five-day courses on improved production techniques between April and October, 1956. The subjects included metal cutting, metal forming, machine tool utilisation, inspection, recently developed production techniques, and various other aspects of production. Each course consisted of illustrated talks, practical demonstrations, group discussions, and films made by the PERA Film Unit.

More than 500 personnel at all levels in industry attended the courses, and it has therefore been decided to establish permanent training facilities for courses of this type at the Association's Melton Mowbray headquarters. Many members have requested that the general course on improved production techniques should be repeated in 1957, and there has also been a demand for courses on a wide variety of subjects. The course on improved production techniques is therefore being held again this year, and preparations are also being made for five-day specialist courses on metal cutting and press-working.

The Aluminium Supply Position

(*Continued from page 62*)

remembered that the conversion of aluminium is the major activity of the industry in this country, and this portion of the selling price of fabricated aluminium depends on wage levels, fuel and transportation. The fabricators and founders are continually introducing new and improved plant and techniques to effect economies, but unless there is stability in these three large factors, it is impossible for that stability to be achieved which will enable aluminium to achieve the expansion which technical factors would otherwise make possible.

That there is great scope for Britain to continue exporting aluminium in semi-finished forms, and also a high proportion of its output in finished aluminium goods, is shown by the figures in the Table VII, which summarises the *per capita* consumption of aluminium in a range of countries. The figures on which this Table is based are those of the apparent consumption in the countries concerned, i.e., virgin metal production, plus imports, plus scrap recovered, with the amount exported deducted. As the standard of living increases, the quantity of aluminium used also increases, and the Table indicates the great margin which exists for further expansion in the less industrialised areas of the world.

REFERENCES

1 West, E. G., *Metallurgia*, Feb., 1953, **47**, 63–69.
2 " Resources for Freedom." Vol. II (Key Commodities) of Report of Paley Commission, June, 1952. U.S. Government Printing office.
3 " The Volta River Project." 3 Vols. (including Appendices), H.M.S.O., 1956.
4 *Revue de l'Aluminium.* (232), May, 1956, 459–464; and (233), June, 1956, 571–574.
5 *Metals and Minerals.* 14, Dec., 1956. 733–734.
6 " Competition between Steel and Aluminium." U.N. Report, Feb., 1954, E.C.C. Geneva, 152 pp.
" Steel and Its Alternatives." U.N. Report, July, 1956, E.C.E. Geneva, 75 pp.

West Instrument Overseas Agents

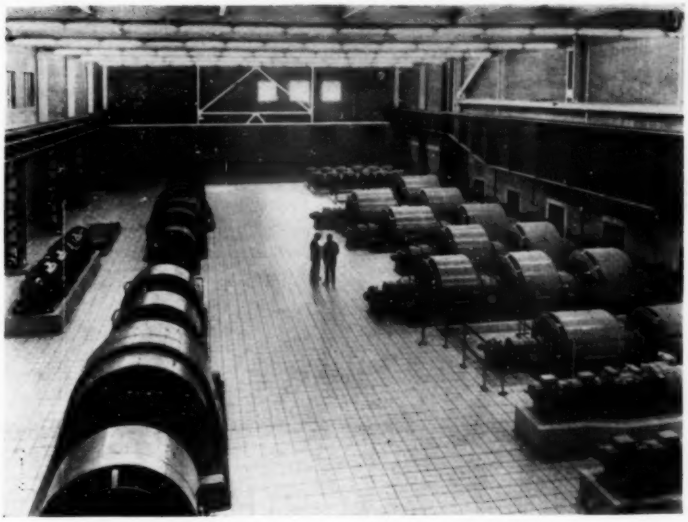
Following a recent trip to the Continent by Mr. J. A. Hartnett, Managing Director, West Instrument, Ltd, new agents have been appointed in Denmark (General Instruments, Blegdamsvej 32, Copenhagen N); Norway (P. D. Waerner A/S, Kirkengaten 1, Oslo); and Sweden (Ingeniorsfirman Siguard Holm, St. Paulsgatan 17, Stockholm.)

Hedin Agents

Hedin, Ltd. of South Woodford, London, E.18, the industrial electric heating specialists, have appointed James R. Turner & Co. of 593, Nitshill Road, Glasgow, S.W.3, sole agents in Scotland.

Electrical Plant for the Metal Industries

Progress in 1956 Reported



Courtesy of The British Thomson-Houston Co., Ltd.

Motor room at the Velindre works of The Steel Company of Wales, Ltd., showing the motor-generator sets and exciters (left) and mill motors (right) for the 5-stand tandem cold strip mill.

THE electrical industry continues to play a major part in the provision of equipment for the metal industries. Electrical drives for rolling mills—whether as new construction or for the modernisation of existing mills—undoubtedly constitute one of the outstanding applications of electricity in this field, but a considerable volume of business concerns the smaller motors, switchgear, rectifiers, and, more recently, electronic control equipment. The following information, based on surveys of the activities of a number of the large electrical engineering concerns in 1956, will give some idea of the extent to which metal working depends on electricity. The review is not exhaustive, and is confined mainly to equipment used in the manufacture of semi-finished products.

The British Thomson-Houston Co., Ltd.

Rolling Mills

Following the two large rolling mill drives installed in Australia in 1955, another large equipment has been put into operation. This is the drive for a 12 in. continuous merchant mill supplied to the order of Australian Electrical Industries Pty., Ltd., for the Broken Hill Pty., Co., Ltd., Kwinana, Western Australia, and comprises six 600 h.p., 200/600 r.p.m. D.C. motors, a 3,000 kW. synchronous motor-generator set, and a large cubical-type control board.

A second large drive to be started up is that for a rotary forge mill for large seamless tubes at Stewarts and Lloyds', Clydesdale Works, Glasgow. This comprises two 2,200 h.p., 55/115 r.p.m. D.C. motors with synchronous motor-generator set for driving gap roll mills, and two 3,000 h.p., 500 r.p.m., 11,000 V. synchronous motors for driving elongators—one of the gap roll motors is to be installed later. Also supplied have been all the auxiliary motors and complete control gear for main and auxiliary drives. The B.T.H. contract included switchgear, transformers, mercury-arc rectifiers, and the supply and erection of all cabling.

The largest drive to be started up is that for the 5-stand tandem cold tinplate strip mill for the Steel Company of Wales, Ltd., Velindre, near Swansea. This mill and drive are very similar to those in operation at the same Company's works at Trostre. The B.T.H. equipment comprises one 1,750 h.p., two 3,500 h.p., one 4,000 h.p., one 5,500 h.p., and one 900 h.p. D.C. motors, together with two synchronous motor-generator sets and control gear. The motors are of the low-inertia type specially developed for these drives, and the control gear embodies the latest combination of amplidynes and magnestats (magnetic amplifiers).

Two outstanding orders for rolling mill plant have been placed with B.T.H. The first is the drive for a 4-stand tandem cold strip rolling mill at the Steel Company of Wales, Abbey Works. It comprises one 3,500 h.p. double unit, three 5,000 h.p. triple units, and one 1,250 h.p. double unit D.C. motors, two synchronous motor-generator sets, control gear, ventilating equipment, and lubrication equipment. The second order is for B.T.H. rolling mill drives and control equipment for the large new steelworks being supplied by the Indian Steelworks Construction Co., Ltd. (Iscon), for installation at Durgapur, India. It comprises two 3,000 h.p., 40/80 r.p.m. D.C. motors forming a "twin-drive" for a 42 in. reversing blooming mill. The equipment to be supplied includes a flywheel motor-generator set, two 600 h.p. bloom shear motors, a large number of Ward-Leonard auxiliary drives, control gear, and ventilation and lubrication equipment.

Rectifiers

During the past 15 to 20 years, the pumpless air-cooled steel-tank type of mercury-arc rectifier has increased greatly in popularity for a variety of industrial applications, but their use for very large rectifier banks, such as are needed for high power electrolytic loads, awaited the solution of a number of problems. These have now been solved, and during the past few years B.T.H. have completed installations for electrolytic

Courtesy of The British Thomson-Houston Co., Ltd.

The control room for the 5-stand cold strip mill at Velindre, showing magnestat control cubicles (left) and contactor panels (right).

duty which included one of 30,000 A., 600 V.; one of 53,333 A., 0/420 V.; one of 28,000 A., 750 V.; and others of smaller size.

World demand for aluminium has led to the erection of new and bigger production plants, and the rectifiers devoted to this single purpose exceed in kilowatts the total of those for all other uses. Until recently, water cooled pumped rectifiers were used, but a big step forward was made in 1955, when Société Péchiney ordered 78 Type MB6/16 pumpless rectifiers for part of the power supply for their new aluminium plant at Edea, in the French Cameroons.

An even more significant step occured early in 1956, when the Canadian British Aluminium Co., Ltd., placed an order with B.T.H. for the entire rectifier installation—of the same pumpless type—for the first two 850 V. 100,000 A. potlines for their new aluminium smelter at Baie Comeau, on the north shore of the St. Lawrence estuary. It is understood that the pumpless rectifier tender showed to marked advantage compared with competing tenders received for ignitrons. The design and operating results with this installation will therefore be of great significance for the future.

In 1951, B.T.H. commissioned pumpless rectifiers totalling 21,000 kW. for a hot strip mill for the Steel Company of Wales. This installation was the first to use pumpless rectifiers for a high-power rolling mill, and it has set a very high standard of service. A somewhat smaller installation now in hand for supplying rolling mill motors totalling 10,300 h.p. for a skelp mill, for the Broken Hill Proprietary Co., Ltd., Australia, uses the latest MB6/16 pumpless rectifiers, and the common D.C. busbar can, when desired, be split into two sections independently controlled at different voltages.

Since the last review, several germanium rectifiers have been completed, including a 1,000 kW., 225 V. set for I.C.I., Ltd., (the first in commercial service); a 2,000 kW., 250 V. set for Société Péchiney; two 15,000A., 18 V. sets for the Steel Company of Wales; two 75,000 A., 18 V. sets for Richard Thomas and Baldwins: and a 30,000 A., 25/50 V. set for Société Péchiney.

Electric Furnace Equipment

Electrical equipment for the first 400 kW. high-frequency induction melting plant was installed at Wellworthy Piston Rings' Lymington Works five years ago. This year B.T.H. have been asked to increase the available power to about 1,600 kW. For this purpose the Company is supplying a 1,250 kW. motor-generator set, comprising a synchronous motor driving two 625 kW., 1 kc./s. alternators connected in series. Excitation of the alternators is provided by a separate motor-generator set which, in turn, is excited by the electronic regulator automatically controlling the voltage of the high-frequency busbars. Pump units are installed for the high pressure lubrication required when starting the set. B.T.H. are also supplying the associated motor starting switchgear, comprising a Class QA solenoid-operated stator switch, reactor-shorting and field-control cubicles, and oil-immersed reactors.

B.T.H. automatic electrode control equipment has been specified for an 80-ton Birlec arc furnace to be supplied to Samuel Fox & Co., Ltd. This will be the largest capacity furnace of its kind in the United Kingdom, and is a development from the successful 60-ton furnace installed last year.

The year has shown a marked increase in the number of orders for B.T.H. automatic electrode control for arc melting furnaces. Amongst others, two of these equipments have been supplied for 60-ton electric melting furnaces at Round Oak Iron and Steel Works, and three for 40-ton furnaces at Brymbo Steel Works.

Orders have been received from Birlec, Ltd., for several furnace transformers, including two 2,000 kVA., 11,000/215–80 V. units for Henry Wiggin's Hereford Works, and two of 1,800 kVA., 20,000/215–85 V. for Walsingham Steel Company.

Industrial Electronics

Standard Motor Control Equipment.—Several special applications of the standard Emotrol motor control units have been made during the year. In the Birmingham Works of Henry Wiggin & Co., Ltd., ten units are installed on a wire-annealing furnace through which ten independent wires pass during the annealing process. Each wire is wound on to a reel driven by a 1 h.p. motor controlled by an Emotrol unit. Constant linear wire speed is maintained by comparing the reference voltage with the voltage derived from a tachometer generator driven by the wire. The Emotrol units were modified to incorporate an overspeed trip which stops the motor in the event of a wire breakage.

Magnetic Amplifiers.—Mention was made last year of the magnestat control equipments for the new 5-stand strip mill at the Velindre Works of the Steel Company of Wales. Although this was a new system of control for a strip mill, no commissioning difficulties were experienced, and very satisfactory operating results have been obtained. An order for magnestat control of the section generators on a 4-stand tandem cold mill at the Abbey Works of the Steel Company of Wales has been received. There will be a total of approximately 65 magnestats of 11 different types.

Miscellaneous

Works Transport.—Orders have been received from the Yorkshire Engine Company and Ruston & Hornsby for electrical and power equipment for a total of 40 diesel-electric locomotives, ranging from 165 to 400 h.p. Two new sizes of Y.E.C. locomotives, 200 h.p., and 400

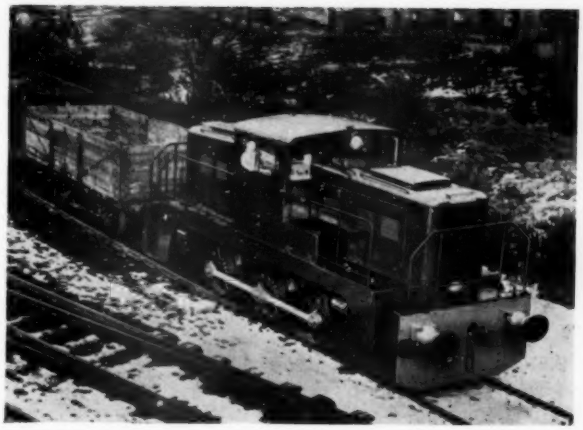
h.p. have been introduced during the year; these are powered by Rolls-Royce engines, two identical 200 h.p. power plants being used in the larger locomotive. In addition, 23 diesel-electric shunters, in 230 h.p. and 460 h.p. sizes, have been ordered from B.T.H. for Iscon, the British consortium which has obtained a contract to set up a complete steelworks in India.

B.T.H. equipment has been supplied for an experimental diesel-electric transfer car designed for use with coke oven plants. This marks a new development in steelworks equipment which holds out great promise for the future.

Cranes.—Several orders have been received for equipments for the travel motion of foundry cranes. The B.T.H. selsyn synchronism system ties-in the speed of the ladle crane with that of the mould conveyor while pouring is in progress.

B.T.H. Stacreep equipments continue to be in demand for many types of crane. A recent order from Joseph Booth & Bros., Ltd., to equip six cranes specifies Stacreep control on all motions.

A new safety device known as Collimit has been developed during the year. This system was devised to prevent collision between two overhead travelling cranes working on the same track. Alternatively, where two cranes are working at different levels in the same bay collision may be prevented between the lower crane and the load or hook above. End limit protection can also be provided by using a slightly different electrical arrangement. The system will always 'fail to safety.'



Courtesy of The British Thomson-Houston Co., Ltd.

400 h.p. Janus diesel-electric locomotive with B.T.H. electrical equipment, Rolls-Royce engines, and Yorkshire Engine Company mechanical parts.

An order has been received for the electrical equipment for the fifth orebridge for the Margam Works of the Steel Company of Wales. The four earlier bridges are already fitted with B.T.H. equipment. A germanium rectifier will be used on the new orebridge to supply the 50 h.p., 230 V. apron hoist motor, several trolley wires being eliminated as a result.

New or Revised British Standards

Steel Railway Sleepers for Flat Bottom Rails
(B.S.500 : 1956) Price 3s. 6d.

First published in 1933, this standard has been revised to provide for the change in practice in ordering railway sleepers. Requirements in respect of British Standard sections for sleeper bars are no longer included. To cater for those purchasers who prefer to check the dimensional tolerances on the sleeper rather than check the gauge of a short length of test track, full dimensional tolerances are included in an appendix. The standard deals with the quality of steel, provision of test samples, templates and gauges, method of manufacture, cleaning and dipping, and inspection during manufacture.

Leaded Brass Strip for use in the Manufacture of Parts for Clocks, Watches and other Instruments
(B.S.2785 : 1956) Price 5s.

This new British Standard gives requirements for three different compositions of brass with varying lead contents corresponding to alloys designated CZ 120, CZ 119 and CZ 118 in the schedules of wrought copper and copper alloys now in course of preparation. All the materials specified are suitable for clock, watch and other instrument components, and are satisfactory for blanking, drilling, gear-cutting and mechanical engraving. Four grades of tolerance are included for each material, the one to be selected depending upon the application for which the strip is intended. The appendices to the standard deal with "Dimensions of tensile test pieces" and with "Grain sizes." They include a series of photographs reproduced by courtesy of the American Society for Testing Materials.

Aluminium Conductors in Insulated Cables
(B.S.2791 : 1956) Price 3s.

This new British Standard results from the increasing use of aluminium conductors in insulated electric cables. It provides a standard range of aluminium conductors suitable for use as alternatives to the copper conductors specified in B.S.7, B.S.480 and other British Standards for electric cables. The conductor sizes and strand formations given in this standard are closely related to the existing copper sizes, and have been chosen to meet the major needs of users. In most cases the resistance of the nearest equivalent copper conductor is within 10% of that of the corresponding aluminium conductor.

Round Hard Drawn Brass Wire for Springs
(B.S.2786 : 1956) Price 2s.

The request for this British Standard came from the Coil Spring Federation Research Organization, following on joint discussions with the Brass Wire Association. The standard specifies requirements for one grade of wire only, the composition of which complies with that designated CZ 107 in the schedules of wrought copper and copper alloys now in course of preparation.

Copies of the above British Standards are available from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1.

In the New Year Honours List

KNIGHTHOOD

David Stirling Anderson, Director, Royal College of Science and Technology, Glasgow.
John Nornam Dean, Chairman, Telegraph Construction and Maintenance Co., Ltd.
George Robert Edwards, C.B.E., Managing Director, Aircraft Division, Vickers-Armstrong, Ltd.
William Leonard Owen, C.B.E., Director of Engineering, United Kingdom Atomic Energy Authority's Industrial Group.
Frederick John Pascoe., Chairman, British Timken, Ltd.
Charles Percy Snow, C.B.E., Commissioner and Scientific Adviser, Civil Service Commission.

C.B.

B. K. Blount, Deputy Secretary, Department of Scientific and Industrial Research.

O.M.

Sir John Cockcroft, K.C.B., C.B.E.

G.B.E.

Sir Archibald Forbes, Chairman, Iron and Steel Board.

K.B.E.

Sir Christopher Hinton, Member of the Board, United Kingdom Atomic Energy Authority.

C.B.E.

S. Cahn, Managing Director, Goodlass Wall and Lead Industries, Ltd.
C. M. Cawley, O.B.E., Deputy Chief Scientific Officer, Department of Scientific and Industrial Research.
E. L. Champness, M.B.E., Managing Director, Palmers (Hebburn) Co., Ltd.
A. T. Green, O.B.E., Director of Research, British Ceramic Research Association.
O. W. Humphreys, Director, General Electric Co., Research Laboratories.
P. Lloyd, Deputy Director, Research and Development, National Gas Turbine Establishment.
J. Martin, O.B.E., Managing Director and Chief Designer, Martin-Baker Aircraft Co., Ltd.
E. J. Sturgess, Chief Engineer, Shell Petroleum Co., Ltd.
Lieutenant-Commander J. W. Thornycroft, Royal Navy (Retired), Managing Director, John I. Thornycroft and Co., Ltd.

O.B.E.

F. E. Ball, Principal Scientific Officer, Ministry of Supply.
W. Barr, Technical Director, Colvilles, Ltd.
F. G. Brewer, Secretary, The Gas Council.
F. F. Butterworth, Senior Principal Scientific Officer, Admiralty.
J. W. Christelow, Senior Principal Scientific Officer, National Physical Laboratory, Department of Scientific and Industrial Research.
J. F. Coates, Constructor, Naval Construction Research Establishment, Admiralty.
E. G. James, Leader of Valve Group, Research Laboratories, General Electric Co., Ltd.
H. Kronberger, Chief Physicist, Research and Development Branch Headquarters Industrial Group, United Kingdom Atomic Energy Authority.
A. Mathisen, Managing Director, Graviner Manufacturing Co., Ltd.
J. Nadin, General Manager and Director, D. P. Battery Co., Ltd.
R. D. Peggs, Principal, Royal Aircraft Establishment Technical College, Ministry of Supply.
A. J. Penn, Chief Engineer, Aero Gas Turbine Division, D. Napier and Son, Ltd.
A. H. Roche, Telecommunication Engineer in charge of Submarine Cable System Development and Production Division, Standard Telephones and Cables, Ltd.
Group Captain R. G. Slade, Chief Test Pilot, Fairey Aviation Co., Ltd.
H. K. Worship, General Manager, Thorpe Road Works, Laurence Scott and Electromotors, Ltd.

M.B.E.

T. L. Barnes, Director, Alford and Alder (Engineers), Ltd.
J. H. Bowden, Service Manager, Mirrlees, Bickerton and Day, Ltd.
A. E. Coe, Senior Experimental Officer, Ministry of Supply.
C. H. G. Croad, lately Chief Foreman (Technical Grade I), Royal Mint.
W. C. Cropper, Group Leader, Research Laboratories, General Electric Co., Ltd.
Miss E. F. Dilbeck, Senior Executive, British Iron and Steel Federation.
W. Drakeford, Works Manager, Armstrong Siddeley (Brockworth), Ltd.
C. H. Evans, Personnel Manager, Automatic Telephone and Electric Co., Ltd.
B. Fullman, Chief Information Officer, British Non-Ferrous Metals Research Association.
H. I. W. Gordon, Test House Manager, Colvilles, Ltd.
J. H. Gray, Senior Mechanical Designer Draughtsman, W. H. Allen, Sons and Co., Ltd.
W. H. Hopkins, Works Manager, E.M.I. Factories, Ltd.
J. F. Howey, Works Manager, Clarke Chapman and Co., Ltd.
J. Lindsay, Chief Generator Erector, Bruce Peebles and Co., Ltd.
F. E. B. Long, Welfare Officer, Staff Department, Shell-Mex and B.P., Ltd.
E. A. Middleditch, General Production Manager, De Havilland Aircraft Co., Ltd.
J. Mountain, Senior Works Foreman, Thomas Marshall and Son, Ltd.
J. Naylor, Manager, Boiler Shop, Cammell Laird and Co., Ltd.
C. W. Paul, Deputy Manager, Harland and Wolff, Ltd.
W. T. Richards, Technical Class Grade B, Atomic Weapons Research Establishment.
A. H. Sherratt, Works Engineer, Standard Motor Co., Ltd.
Major E. A. Shipley, R. A.(Retired), Senior Scientific Assistant, Royal Military College of Science, War Office.
F. H. Smart, Assistant Manager, Royal Ordnance Factory, Cardiff.
F. C. B. Smith, Chemist II, Ministry of Supply.
G. J. K. Smith, Head Foreman Shipwright (Steel), Swan, Hunter and Wigham Richardson, Ltd.
A. W. Southerton, Inspector, Royal Aircraft Establishment.
W. W. Syrett, Export Manager, E. K. Cole (Radio Division), Ltd.
Miss M. K. Walshaw, Private Secretary, Thos. Firth and John Brown, Ltd.
D. B.-Webbe, Mechanical and Electrical Engineer, Air Ministry.

B.E.M.

W. A. Bosworthick, Assistant Staff Foreman, J. I. Thornycroft and Co., Ltd.
P. Bradley, Assistant Manager, Hadfields, Ltd.
J. A. Cook, Maintenance Engineer, Submarine Cables, Ltd.
V. H. Crozier, Honorary Collector for National Savings, Vickers-Armstrong, Ltd.
J. E. Downing, Chargehand Inspector, Ferranti, Ltd.
J. C. Field, Head Foreman Painter, Harland and Wolff, Ltd.
E. Fleming, Head Foreman, Vickers-Armstrong, Ltd.
F. J. Galbraith, Manager, Assembly Shop, Seddon Diesel Vehicles, Ltd.
E. G. Gale, Foreman Erector, Strachan and Henshaw, Ltd.
H. L. Garrett, Laboratory Mechanic, National Physical Laboratory, Department of Scientific and Industrial Research, Norbiton.
M. Gemmell, Boring Mill Operator, G. and J. Weir, Ltd.
F. W. Gosney, Skilled Aircraft Fitter, Blackburn and General Aircraft, Ltd.
T. Hakesley, Chargehand (Tool and Model Maker), Royal Aircraft Establishment, Ministry of Supply (Reading).
H. F. Hewitt, Skilled Machinist, Veritys, Ltd.
J. Jack, Horizontal Borer Operator, Rolls-Royce, Ltd., Glasgow.
C. B. James, D.C.M., Centre Lathe Operator, Shelvoke and Drewry, Ltd.
P. Legge, Chargehand R. & E. Mechanic, Atomic Energy Research Establishment.
F. B. Lovett, Shipping Foreman, Mobil Oil Co., Ltd.
J. H. Matthews, Labour Officer, Monsanto Chemicals, Ltd.
E. F. Neve, Foreman, Submerged Repeater Manufacturing Shop, Standard Telephones and Cables, Ltd.
A. W. Rowley, Foreman, The General Electric Co., Ltd.
R. Smithers, Senior Foreman, Cooke, Troughton and Simms, Ltd
F. Whitehead, Journeyman Plater, Cochrane and Sons, Ltd.

NEWS AND ANNOUNCEMENTS

Mond Nickel Fellowships

THE Mond Nickel Fellowships Committee announced recently the award of two Fellowships for 1956 to the following applicants :—

MR. R. BANDY (The English Steel Tool Corporation, Ltd.) to study in the United Kingdom, Europe and North America metallurgical research, production methods and quality control with respect to tool steels.

DR. J. HARGREAVES (The United Steel Companies, Ltd.) to study the changes in design, construction and methods of operation of steel making and processing furnaces which are being introduced in the United Kingdom, Europe and the United States to increase the rate and efficiency of production.

The Mond Nickel Fellowships Committee now invites applications for Fellowships of an approximate value of £900 to £1,200 for 1957. Fellowships will be awarded to selected candidates of British nationality with degree or equivalent qualifications to enable them to obtain wider experience and additional training in industrial establishments, at home or abroad, to make them more suitable for future employment in senior technical and administrative positions in British metallurgical industries. Each Fellowship will cover one full working year. Applicants will be required to state details of the programme they wish to carry out. Particulars and forms of application are available from : The Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1. Completed application forms are required by 1st June, 1957.

Institute of Metals

W. H. A. Robertson Medal

THE Council of the Institute has awarded the W. H. A. Robertson Medal for 1956 and premium of fifty guineas to MR. E. GRIFFIN (Chief Engineer, Metal Sections, Ltd., Oldbury) for a paper on "Cold Roll-Forming and Manipulation of Light-Gauge Sections," which was published in the March, 1956, issue of *The Journal of the Institute of Metals*.

Spring Meeting 1957

The 1957 Spring Meeting of the Institute will be held in London from Monday to Saturday, April 29 to May 4, and will be a Joint meeting with the Associazione Italiana di Metallurgia, the Société Suisse des Constructeurs de Machines, and the Schweig Verband fur die Material-prufungen der Technik. At the conclusion of the meeting in London, visits by members of the Italian and Swiss societies will be paid to Birmingham, Sheffield and South Wales.

All the scientific sessions will be held at Church House, Great Smith Street, London S.W.1, with the exception of the May Lecture on "Education in Science and Technology," which Sir Eric Ashly will deliver at the Royal Institution, Albemarle Street. A feature of the scientific sessions will be a whole-day Symposium on "Metallurgical Aspects of the Control of Quality in Non-Ferrous Castings," which has been arranged in association with the Institute of British Foundrymen.

Autumn Meeting

The 1957 Autumn Meeting of the Institute will be held in Glasgow from Tuesday to Friday, September 17th to 20th.

Symposium on Corrosion of Metals in Buildings

THE Corrosion Group and the Road and Building Materials Group of the Society of Chemical Industry are arranging jointly a Symposium on Corrosion of Metals in Buildings, to be held at the Institution of Civil Engineers, Great George Street, London, S.W.1, on Thursday, March 21, 1957, from 9.30 a.m. to 6 p.m. The papers to be presented are as follows :—

The Resistance of Non-ferrous Metals to Corrosion in Buildings, by F. E. JONES.

The Corrosion of Ferrous Metals in Buildings, by J. C. HUDSON and F. WORMWELL.

Corrosion of Metals in Contact with Concrete, by P. E. HALSTEAD.

Aluminium Cladding of Buildings, by E. H. LAITHWAITE and E. W. SKERRYE.

The Performance of Zinc and Zinc Coatings in Buildings, by R. W. BAILEY and H. G. RIDGE.

The Behaviour of Copper in Buildings, by S. BAKER and E. CARR.

Preprints of the papers will be made available to those registering their intention to take part in the Symposium. Non-members of the Society of Chemical Industry will be welcome to attend and to take part in the discussion but a conference fee will be payable. Further particulars and forms of registration may be obtained from the Society of Chemical Industry, 14 Belgrave Square, London, S.W.1.

Conference on Hydraulics

RECENT developments in hydraulic controls and drives will be reviewed at a Conference arranged by the British Iron and Steel Research Association, to be held on March 26th to 28th, 1957, at Ashorne Hill, near Leamington Spa. The chairman will be MR. W. M. LARKE of Stewarts and Lloyds, Ltd., and the papers to be delivered will include the following :—

Works Installations, by MR. R. L. WILLOTT (John Summers & Sons, Ltd.) and MR. F. E. PROBYN (Richard Thomas & Baldwins, Ltd.)

Equipment for Steelworks, by MR. R. G. HAMILTON (Stein Atkinson Vickers Hydraulics, Ltd.)

Forging Press Hydraulics, by MR. F. TOWLER (Towler Brothers (Patents) Ltd.)

Modern Pumps and Hydraulic Motors and their Applications, by MR. F. B. LEVETUS (Keelavite Rotary Pumps and Motors, Ltd.)

Modern Servo Control Systems, by MR. R. HADEKEL (Sperry Gyroscope Co., Ltd.)

Fluidrive and its Applications in the Iron and Steel Industry' by MR. A. VICKERS (Fluidrive Engineering Co., Ltd.)

The Nylon Joint, by LIEUT. D. H. CAMERON, R.N. (Admiralty Engineering Laboratory)

The Work on Seals at the Hydromechanics Laboratory, by DR. D. F. DENNY (British Hydromechanics Research Laboratory)

The Work of M.E.R.L. Fluid Mechanics Division, by MR. D. FIRTH (Mechanical Engineering Research Laboratory)

Further information and details can be obtained from The Technical Secretary, Plant Engineering Division, B.I.S.R.A. Laboratories, 140, Battersea Park Road, S.W.11.

Personal News

FOLLOWING the retirement, for health reasons, of MR. G. W. PRESTON, M.B.E., General Manager of the Copper Development Association, MR. R. B. F. WYLIE has been appointed to the new position of Director of the Association.

MR. H. F. TREMLETT has been appointed Deputy Director of the British Welding Research Association. Mr. Tremlett joined the United Steel Cos., Ltd., in 1932 as a Graduate Apprentice, and transferred in 1935 to the Central Research Department, where he worked under the direction of Dr. Swinden on various welding problems, becoming Head of the Welding Section on its formation.

MR. E. E. KENNARD, Sales Manager, has been appointed to the Board of Cooke, Troughton & Simms, Ltd.

MR. J. SAVAGE has recently joined the Board of the Continuous Casting Co., Ltd., Queens Road, Weybridge. Prior to this appointment, he was Head of the Physics Department of the British Iron & Steel Research Association, and was mainly responsible for research and development on the continuous casting of steel carried out by the Association.

MR. M. V. JACKSON, Technical Representative of the Incandescent Group, has recently changed his address and now resides at Hadfield House, Ecclesshall Road South, Sheffield, 11. Tel.: Sheffield 65927.

MR. F. ROWE, Managing Director of K. & L. Steelfounders and Engineers, Ltd., has been appointed a Director of the George Cohen 600 Group, Ltd., the holding company which controls the 600 Group.

MR. D. L. CAMPBELL, Director of Efco, Ltd., and Metallurgical Equipment Export Co., Ltd., leaves on February 7th on a tour which will include India, the Far East, the Philippines, Australia, Canada and the U.S.A.

MR. H. PATTISON has been appointed Deputy Secretary to General Refractories, Ltd., Sheffield, following the recent death of Mr. D. Morris, and MR. G. LEDINGHAM has been appointed to the position of Chief Engineer of the Company.

MR. W. PITKETHLY has been appointed Manager of the Purchases and Supplies Department of the British Aluminium Co., Ltd., in succession to MR. R. L. C. McDONALD, who has retired.

DR. W. I. PUMPHREY, Research Manager of Murex Welding Processes, Ltd., has been awarded the degree of D.Sc. in Industrial Metallurgy by the University of Birmingham for his work on hardenability, the transformation of steel during continuous cooling and the metallurgy of welding.

MR. R. T. DE POIX has been elected Chairman of the Zinc Development Association for 1957. Mr. de Poix is the Managing Director of Henry Gardner & Co., Ltd., and represents the Canadian zinc producers—the Consolidated Mining & Smelting Co. of Canada, Ltd., and the Hudson Bay Mining & Smelting Co., Ltd.—on the Council of the Association.

McKECHNIE BROTHERS, LTD. announce the appointment to the Board of MR. E. HARTLES, as Commercial Director, and MR. H. F. JAMES as Technical Director.

WILD-BARFIELD ELECTRIC FURNACES, LTD., announce that MR. J. E. ORAM, hitherto Director and General Manager, has been appointed Managing Director of the Company. MR. G. R. BARCLAY, O.B.E., continues as Chairman and DR. F. W. HAYWOOD as Technical Director.

MR. C. L. HELLBERG, J.P., has taken up the position of General Manager of Uddeholm, Ltd., Tool Steel Division, at Crown Works, Northwood Street, Birmingham, 3. He was previously Works Manager in charge of the Lichfield factory of John Harris Tools, Ltd.

MR. F. E. L. BACHE, M.C., has been appointed Chairman of Geo. Salter & Co., Ltd., the West Bromwich spring and spring balance makers, in succession to his elder brother, the late MR. C. S. BACHE.

AFTER a service of nearly 39 years with the British Oxygen Co., Ltd., MR. E. S. LANE has retired from his position as Northern Area Sales Manager of the Medical Division. He will be succeeded by MR. F. B. STEPHENS, who is at present Assistant Area Sales Manager.

MR. W. H. McFADZEAN, Chairman and Managing Director of British Insulated Callender's Cables, Ltd., left London by air on Saturday, January 19th on a round-the-world tour. He expects to be back in this country just before the end of March.

THOS. W. WARD, LTD., announce the appointment of the following Local Directors: MR. E. SPRINGTHORPE, MR. C. N. BRADSHAW, MR. E. WOLSTENHOLME, MR. G. PAGE, MR. R. HADFIELD, and MR. A. KISSACK. All six have spent their entire business life with the Company.

THE Society's Medal of the Society of Chemical Industry, which is awarded not more than once every two years for conspicuous services to applied chemistry or to the Society, has been awarded for 1957 to DR. W. J. WORBOYS.

AUTOMATIC TELEPHONE & ELECTRIC CO., LTD. announce that the Chairman of the Company, SIR ALEXANDER ROGER, has retired from the Board and has accepted the appointment of Honorary President of the Company. He is succeeded as Chairman by SIR THOMAS EADES, who has been Managing Director for the past twenty years. MR. C. O. BOYSE becomes Managing Director.

MR. R. McKINNON WOOD, Chairman of Griffin & George, Ltd., has been appointed Chairman of London County Council for 1957–58.

MR. H. M. SELLS has been appointed Field Manager of the Scottish District of British Oxygen Gases, Ltd.

BRITISH INSULATED CALLENDER'S CABLES, LTD., announce the appointment of MR. C. MURRAY as Manager (Overseas).

MR. E. G CLARKE, Managing Director of Acheson Colloids, Ltd., has been elected to the Board of Directors of Acheson Industries Inc., of New York, the parent Company. Mr. Clarke has also been appointed to the office of Vice-President responsible for European operations.

MR. H. F. AKEHURST has been appointed to the Board of British Insulated Callender's Cables, Ltd., as Director (Overseas Operations).

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Anti-Corrosion Coating

A NUMBER of techniques have been evolved for coating, wrapping or protectively painting surfaces exposed to corrosive atmospheres. Many of these, while effective in certain circumstances, cannot be used where high temperatures are likely, as for example in operating plant, while other materials which are effective in most circumstances may be economically too expensive to apply in particular cases.

It is, therefore, particularly interesting to learn of the development of an entirely new type of asbestos emulsion coating, Flexikote, which is non-inflammable, and can be applied to surfaces such as boiler chimneys that remain at temperatures above 200° F. Tests have shown that it has almost indefinite life, and retains its flexibility and plasticity even when the protected surface is subjected to continuous vibration of flexing. When Flexikote has been applied, either by brush or low pressure spray, on to any type of surface, it will be found that the coating, while dry to handle after 24 hours, remains slightly tacky indefinitely; it never completely dries out or hardens or flakes, and is unaffected by fresh water, brine, sun or frost. Flexikote can be applied to a surface simply wire-brushed free of loose rust, and forms a most tenacious bond which does not permit rust to creep under the exposed edge of the surface. It can be equally well applied to metal and non-metal surfaces, and is ideal as a waterproof sealing compound for brickwork and woodwork. It has therefore clearly many applications in the building industry, where the sealing and water-proofing of roofs, gutterings and drains can be rapidly achieved by its use.

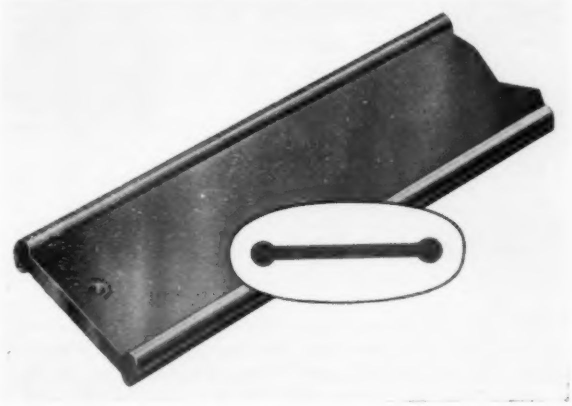
All users of structural steelwork who are faced with the problem of protecting steel members in the form of roof trusses, etc., will find this new material of great value as a rapidly applied and economical means of protection. The coverage obtained from one gallon, properly applied, is as large as 70 sq. ft. and the cost of the material works out as notably less than that of paints which afford less protection. In particular, its flexibility and resistance to high temperatures makes it an ideal medium for factory use and it would appear to have very many applications in this field.

Solvolene Lubricants, Ltd., Reginald Square, London, S.E.8.

"Dog-Bone" Shaped Silver Anodes

ALTHOUGH silver was one of the earliest metals to be electro-deposited on a production scale, the basic electrolyte employed over a hundred years ago is still in everyday use. Until recently, operating difficulties associated with the progressive development of high anode current density, leading to polarisation, had never been satisfactorily overcome.

The Baker Platinum Division of Engelhard Industries, Ltd., has recently introduced a new extruded silver plating anode* having a "dog-bone" cross section, which ensures uniform dissolution throughout the life of the anode. Extensive production tests have shown



that anodes of this new type compare very favourably against conventional sheet anodes. For instance, it has been found that when both types of anode have been operated under similar conditions until only 15% of their original weight remains, the loss of surface area is approximately 3 times greater for the conventional sheet anode than for the "dog-bone" anode. An obvious advantage of such even dissolution is the elimination of anode "shedding" caused by the falling out of small particles at the thin edges developed on conventional anodes after comparatively short periods of use. The freedom from these "shed" particles by the use of the new anodes gives smoother deposits free from roughness.

The new anodes are produced under strict laboratory control, and uniformity of purity and grain size is ensured by routine analysis and testing. They are available 3 in. wide by approximately ¼ in. thick, and in any length to suit requirements. The anodes weigh approximately 4 ounces troy per linear inch, and are drilled at each end to take supporting hooks up to 0·250 in. diameter.

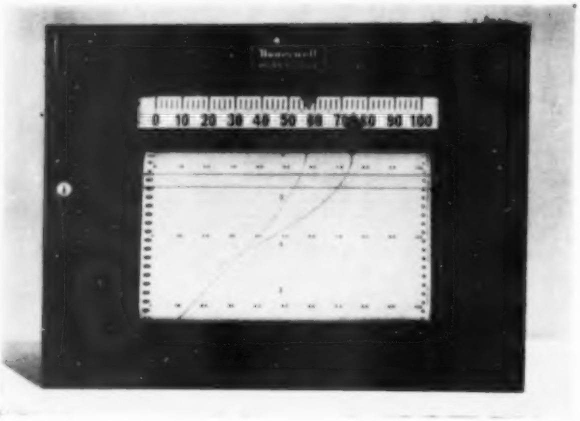
Although this is the first time shaped extruded silver anodes have been offered on a commercial scale in this country, they were recently introduced to the silver plating trade in the United States of America, where the response has been extremely favourable.

Baker Platinum Division, Engelhard Industries, Ltd., 52, High Holborn, W.C.1.

* Patents applied for.

Comparison Measurement of Two Independent Variables

THE simultaneous recording of two independent variables on a common chart facilitates many analyses involving comparison measurements. To meet the requirements of practically all such applications, a new continuous balance strip chart recorder, the Duplex Recorder, has been introduced by Honeywell-Brown, Ltd. This instrument is virtually two orthodox instruments built into the same case; it provides a means of recording two variables on the same chart for purposes of comparison with each other.



The two pens are entirely independent and traverse the full width of the scale without interfering with each other. Since the two measuring circuits are separate, the actuation and range of each pen can be the same or totally different. For example, one measuring circuit can record temperature and the other speed; one voltage and the other current, and so on. A further advantage is the optional provision of a Selsyn-type chart drive motor which allows the two variables to be recorded as a function of motion or displacement. For example, on steel rolling mills, temperature and thickness of the strip is recorded against the length of the strip having passed through the mill.

The Duplex Recorder has already fulfilled a long felt need in several research departments: the Metallurgy Division of the Atomic Energy Research Establishment at Harwell use the Duplex for thermal analysis of uranium and thorium alloys. The Duplex plots cooling and heating curves of a metallurgical specimen in its containing furnace and the temperature difference between the specimen and the furnace.

Honeywell-Brown, Ltd., 1, Wadsworth Road, Perivale, Middlesex.

Pilot Valves

A RANGE of pilot valves for air, hydraulic and vacuum working is now being produced by the Pneumatics Division of the Baldwin Instrument Co., Ltd. These valves are unit constructed and are spool operated. The standard bore size is $\frac{1}{4}$ in., and both 3- and 4-way valves are available with six standard operating mechanisms, namely, push button, cam, single pilot, double pilot, plunger, switch. The units are suitable for use with air or mineral oils at pressures up to 250 lb./sq. in.

The prime purpose of the pilot valves is to operate remotely larger control valves, which in turn operate power cylinders. This means that the control valves can be located close to the power cylinder, ensuring rapid response. Pilot valves can, however, be used to control small power cylinders, or even larger ones if the speed of movement required is relatively low. An application of pilot valves which is becoming increasingly important is to process control systems. In this case, pilot valves are used to operate from some remote position larger control valves which are in some way controlling the flow of fluids.

Pilot valves play a very important part in the sequential control of machine movements. Any number of pilot-operated combinations may be arranged in cascade, so that each power cylinder actuates the control pilot of the next cylinder in sequence. If the last cylinder in the sequence is arranged to re-initiate the first cylinder, a continuous cycling of the entire system can be achieved. Thus, a machine which is powered entirely by air or oil cylinders can be made to run automatically without the need for any external timing device. The main advantage of such an arrangement is that the machine always runs at its optimum speed, regardless of adjustments to cylinder speeds. There is no danger of overlapping taking place between sequential movements, as no movement can take place until the previous one has been fully completed.

The valve bodies and fittings are made of duralumin, anodised to increase resistance to atmospheric corrosion. The pools are of mild steel, precision ground and hard chromium plated, giving a very hard scratch resistant surface which is also proof against water corrosion.

Pneumatics Division, Baldwin Instrument Co., Ltd., Brooklands Works, Dartford, Kent.

Anti-Corrosion Wrapping

Jute hessian treated to protect bright steel parts against corrosion and rusting is now in commercial production, following research work undertaken in the laboratories of the British Jute Trade Research Association. The impregnated hessian, used as a wrapping for bright steel strips and bars, gives full protection under all humid and acidic atmospheric conditions likely to be encountered in transit and storage. It is being supplied in varying widths and on rolls with cardboard centres for reeling off quickly in the wrapping operation. For use with high speed wrapping machines it can be supplied with a dustproof treatment. An important feature is that only single wrapping is necessary for adequate protection of the steel even under extreme conditions. The anti-corrosive treatment is also effective where jute bagging is employed for carrying bright steel products.

The British Jute Trade Federal Council, 64 Barrack Street, Dundee.

Chrome Protector Spray

A NEW product designed to give invisible protection to polished metal surfaces is being marketed by the Pressurised Dispenser Division of Amber Oils Ltd., as the latest addition to their range of Amber Aerosols. It is called Blink Invisible Chrome Protector, and is a clear cellulose lacquer packed in a small aerosol dispenser. When sprayed on polished metal surfaces it forms an invisible protective coating, which remains intact for months; all that is necessary in order to maintain the original polished appearance is an occasional wipe-over with a damp cloth or leather. The sealing action of Blink prevents the deteriorating of chromium plating, and makes it an ideal weather-proof protection for car bumpers, radiator grilles, lamps, mirror backs, etc. The contents of one 6 oz. can (8s. 6d.) are sufficient for the treatment of all the chrome on two medium-sized modern cars.

Amber Oils, Ltd., 11a, Albemarle Street, London, W.1.

CURRENT LITERATURE

Book Notices

METALLURGICAL ANALYSIS BY MEANS OF THE SPEKKER ABSORPTIOMETER

By F. W. Haywood and A. A. R. Wood. Demy octavo, 300 pp., illustrated. Second edition, 1956. Hilger and Watts, Ltd., 9, St. Pancras Way, London, N.W.1. 40s. net postage: inland 1s. 4d., abroad 1s. 6d.).

SINCE the first edition of this book was published, the Spekker absorptiometer has been re-designed and improved, and the number of methods for using it in metallurgical analysis has increased greatly. These changes are reflected in the second edition, which is essentially a new book as it has had to be completely re-written.

It is very much bigger than the first edition, for the most part because it describes so many new analytical methods, but to some extent because it deals fully with two versions of the absorptiometer—the early H560, which alone was considered in the first edition, and the newer H760 model. The early instrument is still serving satisfactorily in many laboratories, so that the description of its design and the account of its use are valuable features of the book.

The book has two main parts. The first deals with the principles of absorptiometry, describes the two instruments, and gives a general account of their manipulation and maintenance. This part concludes with a consideration of the application of absorptiometry to metallurgical analysis. The second part of the book details selected methods of analysis for the elements most commonly associated with others in alloys. The alloy groups covered are those based on aluminium, copper, magnesium and zinc, together with the steels. A comprehensive bibliography guides the reader to numerous original sources and demonstrates clearly the strides that have been taken in absorptiometry since the first edition was published. An appendix supplies a variety of useful information: a composite scheme of analysis with cross-references to the main text; notes on the diagnosis and cure of faults in the Spekker absorptiometer; a list of necessary chemicals and apparatus; and tables of standard metals and alloys.

TITANIUM, ZIRCONIUM AND SOME OTHER ELEMENTS OF GROWING INDUSTRIAL IMPORTANCE

120 pp., demy 8vo. Published by the Organisation for European Economic Co-operation and obtainable from H.M. Stationery Office. Price 10s.

CERTAIN metals and non-metals have assumed increasing industrial importance during and since the war. In this field, the United States gained a considerable technical lead during the war, and the O.E.E.C. Non-Ferrous Metals Committee took the initiative in sending a Mission to the United States to study the production and fabrication of several of these newer metals. The Mission met many American industrialists and research workers, and studied in detail the pilot plants erected by the U.S. Bureau of Mines for the prodution of titanium and zirconium, on which much of current industrial practice is based. They also met Dr. Kroll, who has contributed much to our knowledge of the metallurgy of the new metals.

The Mission has now published its report, which is claimed to contain all the facts needed by mining engineers and metallurgists who wish to start up or extend European production in their sector. It is also likely to prove of interest to a large number of metal users engaged in electronics, aviation and other fields requiring lightness combined with strength and resistance to corrosion and high temperature.

More than half the book is devoted to titanium, covering the general position of the metal in the United States; the production of titanium sponge; melting and fabrication; chemical analysis; utilisation; economic aspects; and an assessment of the future position of the metal. A further quarter deals with zirconium and beryllium, and the report is completed with sections dealing with the refractory metals tantalum, molybdenum and tungsten, and the semi-conductors germanium and silicon.

KEMP'S ENGINEERS YEAR BOOK

62nd edition. Two volumes in case. Crown 8vo, over 2,700 pages, numerous tables and illustrations, index containing 17,000 references. Published by Morgan Brothers (Publishers), Ltd., 28 Essex Street, Strand, London, W.C.2. Price 82s. 6d. (postage 2s. 6d. extra).

FOR more than 60 years, Kemp's Engineers Year Book has been a standard work of reference on engineering subjects. Each year every chapter is reviewed in the light of current knowledge and practice and modified where necessary. The biggest change in the 1957 edition is what is virtually a new chapter on "Gearing." "Iron and Steel" now has additional data on high temperature alloys and the nickel alloys, and all specifications have been brought up to date. "Foundry Practice" has been enlarged to give more detail on shell moulding and to include information on the carbon dioxide process. "Non-Ferrous Metals and Alloys" has numerous revised tables and new text dealing with magnesium alloys and the commercial titanium alloys. Among the numerous additions to "Flow Metering and Mechanical Testing" are text and illustrations dealing with the optical torsion meter, magnetic tests for hardness of steel, the float and taper-tube meter, and the magnetic flow meter. "Grinding, Abrasives and Polishing Appliances" contains a new section of several pages dealing with the methods of shot and grit blasting and the types of machinery employed. Useful additions have also been made to several other chapters.

SPEEDICUT MANUAL OF SCREW THREAD TOOLS

320 pp., 112 tables, numerous illustrations. Published by Firth Brown Tools, Ltd., Speedicut Works, Carlisle Street East, Sheffield, 4. Price 25s.

IN the preparation of this manual, the aim has been to provide an informative and practical guide to promote greater understanding by those whose technical knowledge of screw thread tools is limited, and to serve as a useful reference for more experienced readers.

Whilst various methods of thread production are

dealt with, the main emphasis is on screwing taps. Up-to-date tap and screw thread nomenclature and definitions are given, and many different types of taps in general use are described. The factors involved in their design and maintenance are explained, and information presented to assist in selecting the most suitable kind for a wide range of materials.

The comprehensive lists of tapping drill sizes, the notes on lubrication, speeds, etc., and the discussion of the causes of tap faults and failures in operation and the remedial methods to be adopted, will prove especially useful in the workshop.

Trade Publications

WITH the increasing use of special steels and alloys, advanced machining methods and modern machine tools, the importance of using the correct cutting oil is greater than ever. As a guide to the selection and efficient application of their various specialties, Edgar Vaughan and Co., Ltd., have recently issued a 24-page booklet entitled "Metal Cutting Oils."

METALECTRIC FURNACES, LTD., have recently issued two new Metalectric-Calamari leaflets, Nos. M25 and 26. These cover a range of mains frequency non-ferrous melting furnaces with ratings ranging from 12 kW. to 300 kW. Types GR1, GR2, GR3, GRK/150, GRK/200 and GRK/300 are also ideally suited for the melting of high quality S.G. irons.

IN addition to being a leading manufacturer of stainless steel tubing, the Talbot Stead Tube Co., Ltd., has had a very wide experience of producing tubular fittings, of which details are given in a recently published leaflet.

WE have received from Hilger and Watts, Ltd., leaflets dealing with the following products: Hilger-Negretti D.C. Amplifier; Universal Work Holders for Hilger Inspection Enlargers; Lenses and Condensers; the N.P.L.-Hilger Gauge Interferometer; Schwarz Thermopiles; X-ray Diffraction Cameras and Curved Crystal Monochromator; the Guinier Camera; X-ray Microphotometer; Gauging and Inspection Projectors; the Chekker Projector; and the Angle Dekkor.

"DORMAN LONG ILLUSTRATED 1956" presents the usual annual survey of activities of the companies in the Dorman Long Group, highlighted this year by the visit of H.M. The Queen and H.R.H. The Duke of Edinburgh to the new Lackenby Steel Works in June. Other features include an account of blast furnace and coke oven developments at Cleveland Works, and the activities of associated constructional companies.

THE November issue of *Lab Mail*, published by Glen Creston, Ltd., 41, Church Road, Stanmore, Middlesex, features a number of items of laboratory equipment, including a Simmerstat regulator with output socket, a quick-acting rubber tubing compressor, ultramicro pipettes, and an exposure meter for photomicrography.

Two new publications of Birlec, Ltd., feature, respectively, Birlec-Detroit rocking arc melting furnaces and Birlec continuous conveyor furnaces. The former are used primarily as batch melting units and are in operation for the melting of a wide range of ferrous and non-ferrous alloys. The conveyor furnace booklet deals with electrically and gas-fired radiant tube heated furnaces with conveyors of the cast link, chain and slat belt; mesh belt; roller hearth; pusher; shaker hearth; walking beam; rotary hearth; and rotary drum types; and draw-through furnaces for wire and strip. Brief reference is made to a number of other types of limited application.

WIGGIN NICKEL ALLOYS (No. 42) contains an important article dealing with the welding of Nimoply 75, a composite metal sandwich comprising Nimonic 75 firmly bonded on both sides of a copper inter-layer. Other articles in this issue describe the Inconel components of gas carburizing furnaces in the Ford Motor Company's works, the use of Nimonic DS for flare stack tips, uses of Monel in pickling plant, and the development of a special tungsten nickel for cathode sleeves of valves.

THE December issue of *The Wild-Barfield Heat Treatment Journal* contains the concluding part of an article on spring heat treatment and finishing, a discussion on quenching oils, and a description of the hydraulic control applied to the electrodes of G.W.B.-Tagliaferri arc furnaces.

GEORGE KENT, LTD., have recently issued Publication TP 5010/1156, which is a discussion of problems associated with the disposal of liquid trade effluents, with particular reference to measurement and automatic control, which first appeared in the November 1956 issue of *Power and Works Engineering*. Other new Kent publications include No. 971, which is a Spare Parts List for the Mark 4 power cylinder and position control unit, and No. 986, which illustrates the instrumentation and automatic-control panel for two boilers at the Highveld power station in South Africa.

Books Received

"Principles of Physical Metallurgy." By M. C. Smith. 417 pp. New York and London, 1956. Harper & Brothers and Constable & Co., Ltd. 50s. net.

"Chromium." Vol. I. "Chemistry of Chromium and Its Compounds." By M. J. Udy. 433 pp. New York and London, 1956. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 88s. net.

"Resistance Welding: Theory and Use." Prepared by Resistance Welding Committee, American Welding Society. 163 pp. New York and London, 1956. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 36s. net.

"Metal Statistics." 1946–1955. 43rd Edition. 219 pp. Frankfurt am Main, 1956 Metallgesellschaft, A.G.

"Oxydation von Metallen und Metallegierungen." By K. Hauffe. 389 pp. inc. name and subject indexes and 212 illustrations. Berlin/Gottingen/Heidelberg, 1956. Springer-Verlag. *Ladenpreis*: Ganzleinen DM48.

"Friction and Lubrication." By F. P. Bowden and D. Tabor. 150 pp. London and New York, 1956. Methuen & Co., Ltd., and John Wiley & Sons, Inc. 10s. 6d. net.

"Petrographic Modal Analysis." By F. Chayes. 113 pp. New York and London, 1956. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 44s. net.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

FEBRUARY, 1957. Vol. LV, No. 328

A New Electrolytic Cell for the Isolation of Carbides and Non-Metallic Inclusions in Steel*

By Nils Backstrom, Sakari Heiskanen and Urpo Ilme

VARIOUS methods in use for the isolation of carbides and non-metallic inclusions in steel have been described in detail by Heiskanen.† The most commonly used method is that involving the electrolytic dissolution of the specimen, the conditions being so chosen that the matrix is dissolved and the carbides and inclusions left. These particles must then be collected in some way for further examination. In order to isolate the non-metallic inclusions, the residue from the electrolytic treatment is chlorinated in vacuum by a special technique which leaves the oxides unattacked.

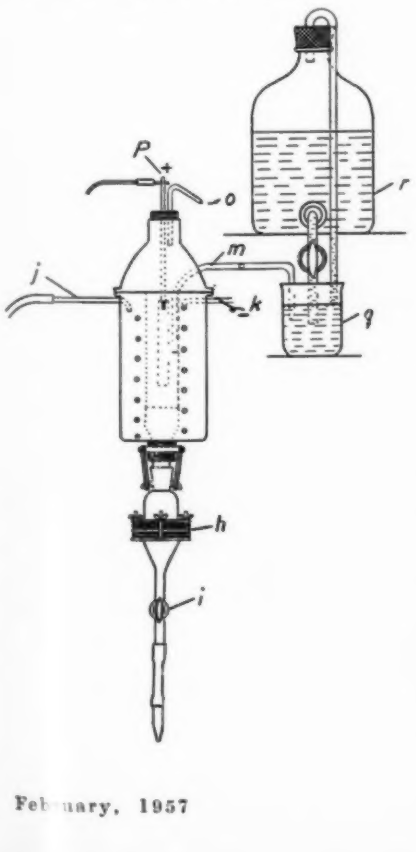
The electrolytic cell hitherto preferred, particularly for the isolation of oxides, is the Klinger-Koch apparatus, in which a protective atmosphere can be maintained during electrolysis. For the isolation of carbides, simpler cells are normally used. These cells have previously been described by Heiskanen.† Since existing cells do not always give satisfactory results, an attempt has been made at Sandviken to develop a new type of cell.

In the light of earlier experience, the new cell should meet the following requirements :—

(1) The anode (the specimen) should dissolve uniformly on all sides.
(2) The anode should be conveniently removable from the cell so that the loosely attached particles can be recovered.
(3) There should be a device for collecting those particles which do not adhere to the anode.
(4) The anode should be visible, for satisfactory control of the electrolysis.
(5) It should be possible to maintain a protective atmosphere in the cell.
(6) It should be possible to use different electrolytes in the anode and cathode compartments.

* Reprinted from *Jernkont Ann.*, **140**, (1956), 812–815.

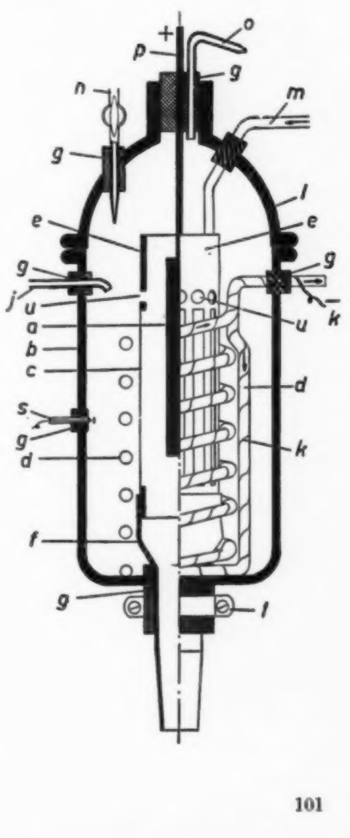
† Sakari Heiskanen, Metallografisk analys och dess tillämpning vid undersökning av stal. *Jernkont. Ann.*, **139** (1955), 78–134.



(a) SPECIMEN, ANODE.
(b) GLASS ELECTROLYTIC CELL (MADE OF STANDARD DETAILS).
(c) CELLOPHANE DIAPHRAGM.
(d) GLASS TUBE COOLING COIL WITH RUNNING WATER.
(e) PLEXIGLASS DIAPHRAGM HOLDER.
(f) GLASS FUNNEL.
(g) RUBBER STOPPER.
(h) FILTERING DEVICE WITH CELLA FILTER, ACCORDING TO KLINGER-KOCH.
(i) GLASS STOP COCK.
(j) PROTECTING GAS SUPPLY TUBE.
(k) CATHODE OF PLATINUM WIRE.
(l) ELECTROLYTIC CELL COVER.
(m) ELECTROLYTE SUPPLY TUBE.
(n) BURETTE FOR SUPPLY OF ACID.
(o) GAS CARRY OFF.
(p) SPECIMEN HOLDER, ALSO FUNCTIONING AS CURRENT LEAD.
(q) VESSEL FOR ADJUSTING THE ELECTROLYTE LEVEL.
(r) ELECTROLYTE STORAGE BOTTLE.
(s) TWO ELECTRODES (PLATINUM AND CALOMEL SIDE BY SIDE) FOR MEASUREMENT OF THE pH OF THE ELECTROLYTE.
(t) STAINLESS STEEL CLAMP.
(u) HOLES IN THE DIAPHRAGM HOLDER.

Fig. 1. (left)—General view of the new device for electrolytic carbide and oxide isolation.

Fig. 2. (right)—Detail view of the new electrolytic cell.



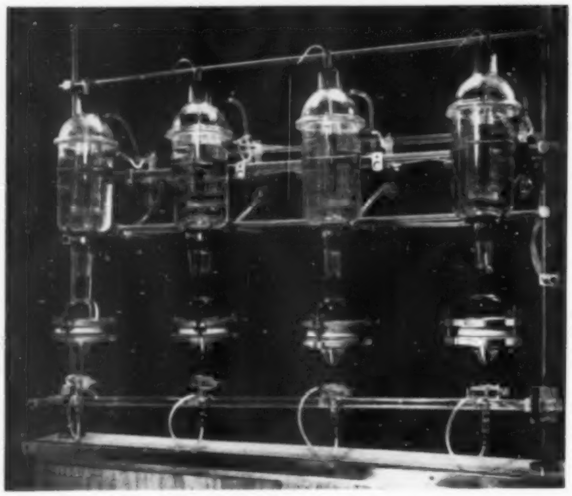


Fig. 3.—Photograph of four electrolytic cells for carbide and oxide isolation at the laboratory of the Sandvik Steel Works Company.

(7) It should be possible to remove the electrolyte continuously and to replace it with fresh solution.
(8) It should be possible to measure the pH of the catholyte and to maintain it constant during electrolysis.
(9) The apparatus should be simple to handle.
(10) The apparatus should be inexpensive and built of as few specially made parts as possible.

The new cell, claimed to fulfil these requirements, is seen in Figs. 1–3. The cathode, consisting of a platinum wire coiled on the glass tube spiral, is placed around the anode. This gives a more evenly distributed current density on the " anode specimen " surface, and enables dissolution to take place more uniformly. The uniform current density also allows the conditions of the electrolysis to be controlled more precisely, and leads to better results.

The specimen can be removed from the bath, and the isolated attached particles are thus easily recovered. During a continuous electrolysis, when the isolated particles partly separate from the anode, they may be collected on a cella filter in the same way as in the Klinger-Koch apparatus. Instead of the cella filter it is also possible to install a settling reservoir, in which the electrolyte and the small isolated particles pass through a narrow tube to the bottom of a larger tube, whilst the electrolyte is removed through an overflow at the top of the large tube.

The anode is easily visible through the glass cell and the plexiglass tube. Cellophane seems to be a very suitable diaphragm material, although it has to be moistened in water to make it conductive if some other medium than water is used as an electrolyte. The cellophane film is wound around the plexiglass tube, and the ends are put into a slit in the plexi tube. The cellophane film is kept in place by means of rubber bands at the top, middle and bottom end of the tube.

Cold water is passed through a glass coil during electrolysis, to prevent the temperature of the solution from rising above that of its surroundings. In the author's experience, this is beneficial to the electrolysis, but if, on the other hand, it is desired to electrolyse at a higher temperature, the coil may be used as a heating device. A protecting gas can be fed into either the upper or lower part of the cell; in the latter case it also acts as a stirring device.

When different solutions are used in the anode and cathode compartments, the cellophane diaphragm must cover the holes (u) in Fig. 2. The anolyte is in this case fed into the anode compartment as shown in the illustration. When the same solution is used both as anolyte and catholyte, the holes are not covered, and in this case the electrolyte is most suitably fed into the cathode compartment, whence it passes through the holes into the anode compartment, and finally through the cella filter.

When only a weak, non-complex-forming, acid is used, the pH of the solution must be kept below a certain value to prevent the formation of iron hydroxide. The pH of the catholyte has a tendency to rise during electrolysis. In such cases the pH can be measured by means of the electrodes (s) and a potentiometer, and in order to prevent it from rising a weak acid solution can be added from a burette (n). In the latter case it is advisable to stir the catholyte by passing the protective gas through the solution.

The electrolytic cell described is relatively inexpensive and made of readily available parts. The cell itself is made of a Jena vacuum desiccator (Jena No. 6032) in which holes have been drilled. The filter attachment is taken from the Klinger-Koch apparatus, and is obtainable from Ströhlein and Co. in Düsseldorf. All the other parts are easily made.

The new cell is very versatile in application, and has been used for more than a year in the laboratory of the Sandvik Steel Works, where it is at present in daily use for the isolation of carbides and non-metallic inclusions in steel.

Acknowledgments

The authors make acknowledgment to the Sandvik Steelworks Company for permission to publish this account and to the Laboratorietjänst, Enskede, for the supply of the cell and other glass components used in the apparatus described.

We are indebted to Einar Öhman, Editor of *Jernkontorets Annaler*, Stockholm, for permission to reproduce this article.

Zero-Mist Officially Approved

Users of chromium plating processes for decorative purposes will be interested to learn that the surface-active fluorinated hydro-carbon agent called Zero-Mist, which is available from the Electro-Chemical Engineering Co., Ltd., of Woking, Surrey, has now been approved officially by the Factory Department of the Ministry of Labour as a suitable agent for suppressing spray in chromium plating operations and for replacing the fans which were previously obligatory.

As a result of tests recently carried out, it has been certified that in each test 3 cu. m. of air were taken from above a chromium plating bath, and in all cases the analyses showed less than 0·005 mg. of total chromium, expressed as chromium trioxide, in the atmosphere. The Chief Inspector is consequently proposing to exempt from Regulation 1 of the Chromium Plating Regulations 1931, baths which are treated with an efficient spray suppressing material.

An Improved Succinate Method for the Determination of Aluminium in Ferrous Materials

By R. I. Parker

Department of Metallurgy, County Technical College, Wednesbury

A method is described for the determination of aluminium in samples containing a large proportion of iron, using an improved succinate separation, by which means accurate results can be obtained reasonably quickly. Titanium is the only interfering element. The method is not suitable for the small amounts of aluminium in aluminium-killed mild steel, nor for samples containing fluorine.

THE need for a routine method for the determination of aluminium in ferrous materials has long been felt, but, to date, no really satisfactory procedure has been devised for routine industrial application. The improved succinate method described here was developed in order to obtain quantitative results from experiments on the corrosive attack of molten aluminium on iron and steel.

These experiments give rise to a series of comparatively small samples (*c.* 1g.), ranging from the unaffected iron or steel to impure aluminium which has absorbed considerable amounts of iron. Analysis of the impure aluminium could be accomplished by the usual titanous chloride volumetric method for iron in aluminium and aluminium alloys, but this is not suitable for the samples at the other end of the range, in which there is a high percentage of aluminium accompanied by a large amount of iron.

In such cases, the aluminium must first be separated from the iron. The classical methods for this separation are due to Chancel,[1] Carnot[2] and Stead,[3] and they all involve precipitation of the aluminium free from iron from a solution containing the iron in the ferrous state. All three methods use sodium thiosulphate as the reducing agent for the iron, this salt being added to the cold solution in Chancel's and Carnot's methods and to the boiling solution in Stead's method. The methods also differ as to the form in which the aluminium is precipitated—a hydroxide in Chancel's method and a phosphate in Carnot's and Stead's methods.

With regard to the particular analytical problem under consideration, these classical methods have two serious disadvantages which render them totally unsuitable. Firstly, for the purpose in view, they are very time-consuming, and this disadvantage is particularly serious when a large number of analyses are to be carried out. Secondly, the methods are not of high accuracy, since the results are somewhat erratic, especially when applied to high percentages of aluminium in the presence of substantial amounts of iron.

Two other well known methods for separating iron and aluminium were considered, but were discarded in favour of the more attractive method developed later. The two methods in question are: precipitation by cupferron (the ammonium salt of nitrosophenylhydroxylamine, $C_6H_5N.NO.ONH_4$), which was recommended by Baudisch,[4] and mercury cathode electrolysis.[5-8] Both these methods are similar, in that iron is first precipitated, together with other elements, leaving a solution containing the aluminium and some other elements, such as chromium, phosphorus and uranium, in the case of the cupferron separation, and titanium, zirconium, phosphorus, vanadium and uranium after mercury cathode electrolysis.

These methods of separation suffer from several disadvantages when a large number of samples have to be handled. This precludes the use of excessively lengthy methods, into which category both of these separations fall. Besides, precipitation with cupferron requires rather critical conditions, including operation at ice-cold temperatures and the removal of a fairly large number of interfering elements, several of which, for example, chromium and phosphorus, might be found in the iron samples to be produced. Mercury cathode electrolysis, on a large scale, introduces problems of cleaning the mercury, to mention but one of its disadvantages.

A disadvantage common to both separations is that they are not selective for aluminium, and this element has to be determined on the iron-free solution, using one of the conventional methods for aluminium. Thus the separation is only a preliminary step, with the result that the whole series of operations involved in the determination of the aluminium content occupies considerable time. For these reasons an alternative method was sought. The nature of the method and its development are described below.

The Succinate Separation

References in the literature dealing with the determination of aluminium show that a method was developed by Willard and Tang in 1937,[9] and was later improved to a limited extent by Boyle and Musser in 1943.[10] Willard and Tang's paper gives details of a series of investigations and the methods evolved for the determination of aluminium in the presence of various other elements and combinations of elements.

One method described was for the determination of aluminium in the presence of iron, by precipitating the aluminium as a basic succinate from a solution containing the iron. Precipitation of the latter is prevented by the low pH of the solution. Precipitation of the aluminium is carried out from a boiling solution containing succinic acid and urea. The latter continuously decomposes, and the liberated ammonia neutralizes the solution, until precipitation of the aluminium commences.

The pH at which precipitation commences is in the range 4·0–4·1, and the final pH of the solution is 4·4–4·5. Iron in its more usual oxidised ferric condition will commence precipitation from such a solution at a pH

value between 2·0 and 2·1. In the ferrous condition, however, precipitation of iron does not commence until a pH of $c.5 \cdot 5$ is reached. Thus, the essence of the method is the prevention of precipitation of the iron by keeping it at all times in the ferrous state.

Willard and Tang attributed the accuracy of this separation and the cleanliness of the precipitate to four factors: (*a*) the denseness of the precipitate; (*b*) the slow uniform increase in pH; (*c*) the homogeneity of the solution; and (*d*) the final low pH.

In its original form, the method was much too long for the application concerned, involving a double precipitation and a boiling time of two hours for each precipitation. However, the method was eminently suitable in that it gave a clean separation of aluminium from the other elements present, the only other element precipitated being titanium. Because of this it was decided to carry out an investigation to see if the method could be improved, with a reduction in the time factor as the main objective.

Experimental Work

One alteration to the original method was made before the experiments were actually commenced, namely, the substitution of potassium metabisulphite and hydroquinone as a means of reducing the iron in place of ammonium metabisulphite and phenylhydrazine. Willard and Tang state that hydroquinone is a less satisfactory reducing agent than phenylhydrazine, but it was decided to use the former as it is a more convenient and stable reagent. The metabisulphite reduces the iron in the first instance, and the other reducing agent is added to maintain reduction in the later stages of the determination.

The potassium metabisulphite/hydroquinone combination is perfectly satisfactory and was used throughout the experiments. It gives excellent results, provided that analytical reagent quality metabisulphite is used: other grades should not be used, as they often vary widely in composition, and may not maintain complete reduction owing to low metabisulphite content. Similarly, very old batches of hydroquinone should be avoided.

For the purposes of the experiments a 1 : 1, iron : aluminium solution was first made up by dissolving 0·5 g. of pure aluminium in caustic soda, combining it with a solution of 4·305 g. iron alum (≡ 0·5 g. iron) in dilute hydrochloric acid, and making up to 250 ml. For each individual test determination, a 50 ml. aliquot of the above solution was used, this quantity of solution being equivalent to 0·100 g. aluminium.

Except for the aforementioned change in reducing agents, the original Willard and Tang method was applied to the test solution, all results obtained being 3–4% low. These low results arose from the difficulty of filtering and washing the gelatinous precipitate, which causes losses. The reason for the gelatinous nature of the aluminium succinate was over-neutralization of the solution with ammonia before precipitation commenced.

If neutralization of the solution is left entirely to the decomposition of urea, precipitation only commences after boiling for about 45 minutes, because of the high original acidity. This delay is avoided by adding ammonia, stopping just before precipitation commences, this point being indicated by the first discernible colour change with methyl orange. Unfortunately, the gap between the pH at which this initial change occurs ($c.$ 3·2) and the pH at which the precipitate first appears is small, so that over-neutralization is not easily avoided. Over-neutralization produces a bulky gelatinous precipitate, with all its attendant troubles, and even if this precipitate is re-dissolved with acid, the subsequent precipitate is still gelatinous.

Because of this necessity to avoid adding too much ammonia, a change of indicator was deemed advisable, and thymol blue was substituted for methyl orange. The colour change of the former takes place at a pH value (c 2·0), which still leaves the solution acid to methyl orange, there being no danger of over-neutralization as long as the ammonia is added carefully.

The amended method was first tested on pure aluminium solutions, which were obtained by dissolving pure aluminium in caustic soda and neutralizing with hydrochloric acid. At the same time, it was decided to determine whether two hours boiling and double precipitation, as specified by Willard and Tang, were really necessary. Consequently, boiling times for the amended method were reduced to half and one hour periods, and precipitation was carried out only once. Excellent results, all lying within the range 99–100%, using solutions containing 100 mg. aluminium were obtained. Next, this amended method was applied to 1 : 1 and 10 : 1, iron : aluminium solutions, made from iron alum and pure aluminium. Recoveries of 99–100% were obtained on 100 mg. aluminium, boiling for half an hour only.

The next aluminium solution was made up by dissolving 17·57 g. Analar potassium alum (≡ 1·0 g. aluminium) in water, and making up to 500 ml., so that, as before, 50 ml. aliquots contained 100 mg. aluminium. This was a simpler, cheaper, and more convenient way of obtaining a solution. Iron was added to each aliquot in the form of a solution of 1·0 g. Armco iron in hydrochloric acid, making a 10 : 1, iron : aluminium solution.

Here, the only difficulty was dissolving the Armco iron, a very slow process with hydrochloric acid alone. To speed solution, a little nitric acid was added, with the desired result. It was found, however, that the method would not work satisfactorily in the presence of nitric acid, so that the nitrate radical had to be eliminated. Nitric acid reacts with the hydroquinone to form complex oxidation products and this, due to consumption of the reducing agent, causes incomplete reduction of the iron, so that a clean separation is not obtained.

As an alternative, a little copper sulphate solution (0·001–0·002 g. copper), was added to speed up solution by setting up a galvanic couple. The increase in the rate of dissolution was only slight, however, so that a third method was tried. This consisted of adding a little bromine water to the hydrochloric acid. This was very satisfactory, as it considerably increased the rate of solution, and any excess bromine was readily removed by subsequent boiling. This method of effecting solution was later incorporated in the final method developed for steel, as the latter is rather slow to dissolve in hydrochloric acid alone.

The potassium alum/Armco iron solutions were tested, thymol blue being used, and boiling taking place for half an hour with only one precipitation. Excellent results showed recoveries ranging from 98–100%. Even using thymol blue, ammonia has to be added very carefully until the colour just changes, beyond which point a further small addition causes pre-precipitation with all its attendant difficulties and disadvantages. Furthermore, addition of ammonia until the colour of the indicator just

changes still leaves an interval of about 15 minutes boiling time before the precipitate appears.

Because of this, it was decided to try and find a more suitable alkali for neutralizing the solution. A cheap and readily available substitute is sodium bicarbonate, which was tried and proved ideal for several reasons. Firstly, it was discovered that even if the solution were over-neutralized, the precipitate could be redissolved in hydrochloric acid without a gelatinous precipitate resulting. Secondly, it obviated the necessity for an indicator, and thirdly, and most important, the pre-precipitation boiling time was reduced to a few minutes by adding the hydrochloric acid carefully, just to dissolve the precipitate. To ensure a low free-acid content, and consequently a short pre-precipitation boiling time, the solution was re-acidified with 15% hydrochloric acid instead of 50% hydrochloric acid.

This modification of the method was tested with 10 : 1, iron : aluminium solutions made up by adding 1·0 g. mild steel dissolved in concentrated hydrochloric acid plus bromine water to 50 ml. of the pure aluminium solution. The first series of results were all low, within the range 95–96% recovery. It was thought that this might have been due to too low solution bulk at the end of the precipitation stage, and/or too short a precipitation time. Consequently, further 10 : 1, iron : aluminium solutions were treated, boiling for 45 minutes after the appearance of the precipitate and keeping the bulk above 500 ml. during precipitation. This time, results of a large number of determinations were all accurate to 2 mg.

The next step consisted in removing the ammonium radical from the method entirely, in order to ensure complete freedom from the possibility of producing gelatinous precipitates. Further evidence in favour of its removal is afforded by the following statement,[11] "that precipitation of aluminium chloride by ammonium chloride and ammonia should be banned from practical use, for these methods produce the worst results"—which tends to suggest that it is the ammonium radical that is the cause of the trouble.

The only ammonium salt remaining in the method at this stage of the investigation was the chloride, added at the same time as the succinic acid, urea and hydroquinone. This ammonium salt was not replaced, since the chloride radical served only to keep zinc in solution, this element being unimportant in the materials under consideration. This completed the investigation as far as the reduction, precipitation and filtering stages were concerned, subsequent work being confined to problems relating to the solution of samples.

The method was finally tested using 20 : 1, iron : aluminium solutions obtained as before (2·0 g. mild steel), all results falling between 98 and 100% recoveries (samples contained 0·100 g. aluminium). The total time for a determination was approximately 2 hours after solution, a reduction of 3½–4 hours on Willard and Tang's original method.

The only other element which is co-precipitated with the aluminium, and which is likely to be found in ferrous materials in significant quantities, is titanium. This element, in its tetravalent form, is precipitated at a pH of 0, so that obviously it cannot be kept in solution. Thus, any titanium present will appear as titania (TiO_2), combined with the alumina (Al_2O_3) in the ignition residue. As this cannot be avoided, titania, when known or suspected to be present in the residue, must be determined and subtracted to give the net weight of alumina. This determination is conveniently accomplished by the usual hydrogen peroxide colorimetric method, after fusion of the weighed residue with potassium bisulphate.

Solution of Samples

The hydrochloric acid/bromine water method devised for pure iron has already been described, and its application to steels was made because of the more rapid rate of solution obtained, compared with solution in hydrochloric acid alone.

For pig iron and cast iron, nitro-sulphuric acid, which gives a rapid rate of solution, is unsuitable due to the nitric acid, the effect of which has already been described. Hydrochloric acid and bromine water, on the other hand, only dissolves irons slowly, so that nitro-sulphuric acid was, in fact, tried, attempting by various methods to remove the nitrate radical after obtaining a solution.

The first two methods tried were : (*a*) evaporating to fumes of sulphur trioxide ; and (*b*) evaporating to dryness, followed by baking. Neither of these methods removed the nitrate radical completely. A third suggested method was to add sulphamic acid to the solution *after* adding the metabisulphite. The latter reacts with nitrates to form nitrites which are destroyed by sulphamic acid. Unfortunately, this method, although superior to the first two, still left sufficient nitrate to cause excessive discoloration of the solution, indicating that dissolution would have to be accomplished in the absence of the nitrate radical. This was achieved with a mixture of hydrochloric acid and potassium persulphate, a strong oxidising agent. It was later suggested that hydrogen peroxide would be equally as effective as potassium persulphate, with the added advantage that the alkali salt additions to the method would be reduced.

Slag samples were first treated by a method used in some steelworks laboratories for basic open-hearth slags. In this method, the slag is digested with concentrated hydrochloric acid, evaporated to dryness, baked and redissolved, after cooling, in hydrochloric acid plus water. This was followed by filtration of the silica and precipitation of aluminium succinate from the filtrate by the usual method.

This method of treating slags was tested, using a cupola slag supplied by the British Cast Iron Research Association. The average result obtained on a number of determinations was 10·9% alumina, after deducting titania determined in the residue. This result came in the middle of the range of figures supplied with the slag sample, and, moreover, at 0·4%, the "spread" of results was considerably narrower. However, when the method was applied to some other cupola slags in stock, results were all low, errors being both great and small. It was suggested that these errors might be due to incomplete solution, caused by the sample being too coarse. The same samples were ground to − 200 mesh and the determinations repeated, this time with satisfactory results. This was presumably because the fine grinding completely liberates the soluble part of the slag from the insoluble silica particles.

The completed methods were then handed over for testing to an independent body, who reported excellent results except in the case of slags which contained fluorine, or those which required the addition of a fluoride for solution. In the case of such slags, results were high and the ignition residues tended to be rather yellow. The residues were subjected to the zirconium alizarin

lake test for the fluoride radical,[12] which proved the latter to be present in considerable quantities, presumably as calcium fluoride (pale yellow). Therefore, the problem to be solved was the removal of the fluoride after solution of the sample.

The methods tried included fuming with sulphuric acid, fuming with perchloric acid, addition of a borate (borax)—these three after solution in hydrochloric acid—and baking down with sulphuric acid followed by solution in hydrochloric acid. As all the methods tried failed to solve the problem, it was decided to bring the investigation to a close, leaving slags containing fluorine or requiring the addition of a fluoride for solution outside the scope of this improved succinate method for aluminium.

Proposed Method

Solution Procedure

Irons

Dissolve a 2·0 g. sample in 35 ml. 50% hydrochloric acid plus a little hydrogen peroxide in a 400 ml. beaker. Evaporate to dryness and bake well. Cool and take up in 10 ml. concentrated hydrochloric acid followed by hot water. Reheat to boiling and filter through a 30 mm. pad, washing pad and beaker with 2% sulphuric acid. Transfer the filtrate to a 1,000 ml. Phillips beaker and proceed as under Analytical Procedure.

Steels (Note 1)

Dissolve a 2·0 g. sample in 35 ml. 50% hydrochloric acid plus a little bromine water (added at intervals) in a 400 ml. beaker. When dissolved, transfer to a 1,000 ml. Phillips beaker and proceed as under Analytical Procedure.

Slags (Note 2)

Transfer a 1·0 g. sample (Note 3) to a 400 ml. beaker and dissolve in 20 ml. concentrated hydrochloric acid. Evaporate to dryness and bake well. Cool and take up in 30 ml. 50% hydrochloric acid followed by hot water. Reheat to boiling and filter through a 30 mm. pad, washing pad and beaker with hot water. Transfer the filtrate to a 1,000 ml. Phillips beaker and proceed as under Analytical Procedure.

Analytical Procedure

Irons, Steels and Slags

If necessary, dilute the solution to *c.* 200 ml. and insert a glass rod to prevent bumping whilst on the hotplate. Bring the solution to the boil and add 5 g. potassium bisulphate (Note 4). Continue boiling for 1–2 minutes, dilute with water to *c.* 400 ml. and bring to the boil. To the boiling solution add 5 g. succinic acid, 4 g. urea and 5 g. hydroquinone (Note 4), all roughly weighed. Boil for 1–2 minutes and remove from the hotplate.

Carefully add sodium bicarbonate (solid or solution) to the solution until a permanent precipitate is obtained. Just take up their precipitate by adding 15% hydrochloric acid (Note 5). Make up to *c.* 600 ml. and heat to boiling. Continue boiling for 45 minutes after the precipitate appears (Note 6). Remove from the plate and filter immediately through a 30 mm. pad. Bobby out the beaker and wash pad and beaker with 2% ammonium nitrate solution. Ignite the pad and precipitate to a constant weight at bright red heat (*c.* 20 minutes) (Note 7) cool and weigh as Al_2O_3.

If titanium or titania is known or suspected to be present, the ignition residue must be fused with potassium bisulphate, and the amount of TiO_2 in the residue determined, using sulphuric acid and hydrogen peroxide. The weight of the TiO_2 so found must be subtracted from the weight of the ignition residue to give the net weight of Al_2O_3.

$$\text{Wt. of aluminium} = \text{wt. of } Al_2O_3 \times 0{\cdot}53$$

On a 2 g. sample

$$\%\ \text{aluminium} = \frac{\text{wt. of } Al_2O_3 \times 0{\cdot}53 \times 100}{2}$$

$$= \text{wt. of } Al_2O_3 \times 26{\cdot}5$$

Notes

Note 1—This method is not suitable for the determination of very small amounts of aluminium, such as might be found in an aluminium-killed mild steel, for instance.

Note 2—This method is not suitable for slags which contain fluorine, or which require the addition of a fluoride to effect solution.

Note 3—Solution will not be effected unless the sample is finely divided—at least −100 mesh.

Note 4—Use analytical reagent grade of metabisulphite and fresh hydroquinone, or complete reduction of the iron may not be maintained at all times.

Note 5—This stage should be carried out carefully, as the reaction is very sluggish and over-neutralisation will result in unnecessary waste of time.

Note 6—Do not let the liquid bulk fall below *c.* 500 ml. or loss may occur.

Note 7—Too long an ignition time may cause fusion of the residue to the crucible, particularly if the temperature is rather high.

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REFERENCES

1 Chancel. *Comptes Rendues*, (1858), **46**, 987.
2 Carnot. *Comptes Rendues*, (1881), **93**, 154; (1882), **94**, 1313; (1884), **98**, 917; and (1890), **111**, 914.
3 Stead. *J. Soc. Chem. Ind.*, (1889), 965; and (1890), 20.
4 Baudisch. *Chem. Ztg.*, (1909), **33**, 1298.
5 Cain. *J. Ind. Eng. Chem.*, (1911), **3**, 476.
6 Lundell, Hoffman and Bright. *J. Ind. Eng. Chem.*, (1923), **15**, 1064.
7 Brophy. *J. Ind. Eng. Chem.*, (1924), **16**, 963.
8 Maxwell and Graham. *Chem. Rev.*, (1950), **46**, 471.
9 Willard and Tang. *Ind. Eng. Chem., Anal. Ed.*, (1937), **9**, 357.
10 Boyle and Musser. *Ind. Eng. Chem., Anal. Ed.*, (1943), **15**, 621.
11 C. L. Duval. "Inorganic Thermo-gravimetric Analysis," p. 115.
12 F. Feigl. "Spot Tests," p. 203.

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